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ALLERGY IN OTORHINOLARYNGOLOGY AND OPHTHALMOLOGY. A REVIEW OF THE RECENT CURRENT LITERATURE.

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A review of the literature on the subject of allergy from the standpoint of ophthalmology and otolaryngology for the year 1939 shows a comparatively small number of presentations devoted to this subject. In general, there appears to be an increasing interest in the part played by allergy in paranasal sinal disease. There are, however, far too many articles on the subject in which allergy is given no consideration whatsoever. On the other hand, in those instances in which allergy is considered, there are definite indications that often allergic management has not been adequate. There is great need for better co-operation between the allergist and the otolaryngologist. Only by this co-operation can certain important factors be determined. For example, further statistical studies should be made on the incidence of allergy among nasal and sinal cases in general, and on the incidence of polypoid or hyperplastic changes in nasal allergy, hay fever and asthma. The frequency of reversible, as compared with irreversible, changes in these cases should also be determined. The comparative incidence of acute and especially chronic infections and more definite indications for surgical interference remain yet to be estimated.

PHYSIOLOGY.

In studying the action of drugs on the nasal mucosa, Proetz[1] made his observations on the cilia *1.* of the living rabbit,

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2. of extirpated rabbit mucosa, and *3.* of extirpated human mucosa.

The action of *1.* benzedrine inhalers without oil of lavender and with oil of lavender, and *2.* 1, 2 and 3 per cent solutions of amphetamine in liquid petrolatum were reported as follows:

The benzedrine inhaler without oil of lavender and with oil of lavender showed no deleterious effect on ciliary action.

The direct application of amphetamine stopped all ciliary motion instantly. The application of 1, 2 and 3 per cent solutions in liquid petrolatum caused slowing of ciliary action within a few minutes.

In the same type of experiments it was noted that alcohol in any concentration in distilled water stops ciliary beat in a few seconds, the rapidity depending only on the strength of the solution. When the alcohol was diluted with Locke's solution, however, it was fairly well tolerated, especially in 5 and 10 per cent dilutions. A 20 per cent solution, however, caused cessation of motility in 20 to 30 minutes, and the cilia could not be resuscitated.

Agents capable of reducing surface tension, such as decylbenzene sodium sulfonate, monobutyl diphenyl sodium monosulfonate and monobutyl phenyl phenol sodium monosulfonate, were applied in 0.1 per cent solution. These agents caused disintegration of the epithelial surface and cessation of ciliary action.

The effect of ether, chloroform and nitrogen monoxide on the cilia of the trachea as well as the sinuses of rabbits was also observed. These three anesthetics had no effect, *per se*, on ciliary activity when administered in gaseous form. The cold produced by their evaporation may paralyze the cilia while it continues. This was especially notable with ether and chloroform. Actual contact of the fluid, however, was noted to be disastrous to the membrane.

BIOCHEMISTRY.

Mittermaier[2] reports further observations on the chemical aspects of nasal polyposis. He found that the protein content of the polyp fluid ranged between 0.5 per cent and 1 per cent, while the protein content of normal serum is about 7 per cent. This indicates that the polyp is not formed by the stasis of

fluid. On the other hand, Mittermaier is of the opinion that it is probably caused by a greater permeability of the blood vessels. He suggests the following simple test to determine the allergic response in cases of polyposis: 0.02 cc. of physiologic saline solution is injected intracutaneously. A small wheal is formed, followed by a secondary wheal. The secondary wheal disappears in about six to 12 minutes. In patients with hyperplastic states who show a tendency to edema and polyposis he found that usually the secondary wheal does not occur, and the primary wheal disappears in a much shorter time than six minutes. It is concluded that persons who show a rapid resorption of saline solution have a tendency toward polyposis, probably due to a certain degree of retention of salt in the skin. In treatment, he suggests a salt-free diet leaning toward the alkaline side of the acid-base ratio, and a careful avoidance of any tendency to acidosis.

ALLERGY OF THE NOSE AND PARANASAL SINUSES. DIAGNOSIS AND TREATMENT.

In a review of 3,657 consecutive cases seen in eye, ear, nose and throat practice, Kuhn[3] noted that 720, or 20 per cent, had nasal complaints. An analysis of this group of 720 cases showed that 140, or 19.4 per cent, had nasal allergy. This group of cases of nasal allergy constituted 3.7 per cent of the total reviewed.

Among the 140 cases of nasal allergy, the cytology of the nasal secretions was determined in 88. In 26 cases an eosinophilia of over 50 per cent was found. In 34 it varied from 10 to 50 per cent. In 28 cases there was an eosinophilia of 1 to 10 per cent. In 52 cases no smears were made. The skin tests showed the following positive reactions: Inhalants, 57 (40.7 per cent); foods and contacts, seven (5 per cent); and inhalants, foods and contacts, 76 (54.3 per cent).

The results of treatment were as follows: Satisfactory by allergic management only (avoidance and desensitization), 67 (47 per cent); satisfactory by allergic management plus local treatment, 38 (27 per cent); satisfactory by allergic management plus surgical treatment, 30 (21.7 per cent); and failures, five (3.5 per cent).

A consideration of Kuhn's statistics shows that only 19.4 per cent of the nasal cases had allergy. Our percentage of

nasal allergy has been between 40 per cent and 50 per cent of all nasal cases.

Opheim[4] reports his observations on a large number of allergic cases, with particular attention to symptoms, operative findings and histologic sections, and concludes that 25 per cent of all cases may be included under the designation of "rhinosinusitis chronica hyperplastica allergica." Roentgen studies and cytologic examinations are emphasized as important in diagnosis. Opheim advises surgical intervention only for major anatomic defects and states that he has had good results from the use of nonspecific desensitization with "novoprotein" (a plant albumin).

Kern and Schenck[5] express the opinion that polypi are in every instance an evidence of an allergic basis, and state that avoidance of, or desensitization with, allergens yields clinical results far superior to the old routine of surgical removal alone with its distressingly frequent recurrence of the polyps. Advice against surgical removal during the pollinating seasons is emphasized. They further advise the removal of polyps only when they are obstructive.

Rackemann and Weille[6] discuss the relationship of disease of the paranasal sinuses and asthma. In a large series of cases in which operative procedures were performed upon the sinuses, they found that in general the end-results were often disappointing. Among the cases in which tissue from the antrums was studied microscopically, pus pockets were found in the mucosa in about 10 per cent of the cases. No definite relationship was noted between the results of operative treatment and the degree of improvement of the asthma. They noted, for example, that in some instances asthma was relieved for months or years, but they state that the chances were nearly nine out of 10 that sooner or later the asthma would recur. Rackemann and Tobey emphasize the point that sinusitis is a part of the asthmatic syndrome, and not the cause of it. In about a third of the new patients with asthma which they observed, operations had already been done on the nose or on the nose and sinuses. About one-half of the patients had lesions at the time of the examination. It was finally concluded that if the nature of the sinal lesion indicates operation for itself without regard to the asthma, operative treatment will do good, but the good will be only partial and only temporary in most cases because the sinal lesion is a part of the picture and not a cause of it.

Black[7] calls attention to the importance of differentiating between chronic sinusitis and perennial hay fever. In spite of Roentgen evidence of thickened mucosa, more reliance is placed upon the pale mucosa, the watery discharge and the increase in eosinophiles. With the addition of positive skin reactions the part played by allergy is of further significance. It is advised that surgical treatment be confined to removal of gross obstructions. Black advises the oral administration of ephedrine or benzedrine in preference to their local application.

Some difference of opinion has existed for some time as to the comparative value of transillumination and X-ray of the sinuses. It is generally agreed, however, that the X-ray is more exact and a more definite method of diagnosis. Waldapfel[8] states that in the simple transillumination a difference in darkness of the maxillary sinus can be caused, not only by a disease of the sinus but also by asymmetry of the two sinuses and varied thickness of the bone. These physiological anomalies do not play a part in the X-ray examination and do not influence the results. He further points out that, apart from disease of the maxillary sinus itself, darkness in transillumination can be caused not only by thickness of the bony walls and asymmetry of the maxillary sinus but also by infiltration of the soft parts, even of slightest degree. In such instances the transillumination may show more than the X-ray. Complete or massive cloudiness in transillumination with negative X-ray findings is to be regarded as significant for infiltration of the soft parts, subcutaneous edema or hematoma, even if no swelling or discoloration of the skin may be evident.

In his discussion of allergic rhinitis, Jones[9] states that it is difficult to differentiate clearly perennial fever and allergic rhinitis. Those cases in which the primary symptoms were sneezing and rhinorrhea, and in which the nasal mucosa was pale were considered as perennial hay fever. The cases with a red mucosa were considered as allergic rhinitis. Is there a justification for making this distinction between a pale and a red mucosa? Considering all cases of allergy in the nose as nasal allergy, there is a definite variation in the type of mucosa observed; namely, normal, slightly pale, markedly pale or edematous, or red. Nasal polyps are usually present with the pale mucosa. There appears to be no reason, therefore, for the introduction of additional terminology.

In a study of the relationship of nasal allergy and other manifestations, Agar and Cazort[10] conclude by emphasizing the following points: *1.* Studies of the nasal and bronchial secretions give the only reliable means of diagnosing infected and infectious asthma; *2.* a submucous resection properly done is of great benefit in a large percentage of cases of hay fever and asthma; *3.* in sinal disease, conservative surgery is preferable and offers good results in inverse ratio to the duration and severity of the asthma.

Patterson[11] discusses his experiences with the external operation of the ethmoidal labyrinth which he advocates in cases of polyposis. He states that by this method the nose may be permanently freed from polyps. Although almost 100 per cent of the cases of nasal polyposis are of allergic origin, no reference is made to this factor.

In discussing the subject of sinal disease in general, Fletcher[12] enumerates such complaints as sneezing, profuse discharge and nasal obstruction, among other symptoms such as headache, pain and fever. He further states that the formation of polyps is the result of long-continued infection. He also remarks that infection from the sinus may spread to the tonsils and adenoids. He defines acute sinal infection as simply a "cold in the head" and chronic sinus disease as "catarrh." An infection is mentioned as the usual cause of disease. Allergy is not considered as an etiological factor in these cases.

In a general consideration of the subject of allergy in otolaryngology and its relation to other manifestations, Hansel[13] discusses the various allergic lesions which may affect the eye, ear, nose and throat, and their relation to manifestations of allergy elsewhere in the body. In nasal and sinal diagnoses a special emphasis is placed on the careful consideration of the following factors: *1.* nasal and sinal symptoms; *2.* the gross pattern changes; *3.* the cytology of the secretions; *4.* X-rays; *5.* histopathologic findings; *6.* bacteriologic findings. In those cases with marked pathologic changes, attention is called to the importance of determining whether complicating infections are acute, subacute or chronic.

In a further consideration of allergy in otolaryngology and its relation to other manifestations, Hansel[14] discusses problems in diagnosis and treatment and illustrates some important points by case reports. From the otolaryngologic stand-

point, a great deal of stress is placed upon the necessity of complete studies of the nose and paranasal sinuses without which atypical cases may be easily overlooked. It is emphasized that radical surgical procedures should be deferred until allergic methods of treatment have been instituted, for satisfactory relief of symptoms and the control of pathologic changes are dependent upon adequate allergic management.

The following reports on the end-results of various types of surgical interference on sinal disease by Hempstead,[15] Faulkner,[16] Salinger[17] and Arbuckle[18] were presented as a symposium before the American Laryngological, Rhinological and Otological Society in Chicago on May 10, 1939. In general, they represent a free discussion of both conservative and radical procedures. It is noteworthy that allergy was considered an important factor in the cause of sinal disease, and it was given more attention than in previous symposia of a similar nature. In general, however, it is evident that more attention should be directed to greater accuracy in diagnosis, utilizing particularly the information obtained from cytologic and bacteriologic studies. There is much need for closer co-operation between the otolaryngologist and the allergist.

A great deal of emphasis should be placed upon the prophylaxis of sinus disease. Acute infections should be properly managed so that the chronic process may not develop. The use of chemotherapy no doubt will play a great part in obtaining better control of the acute and subacute infections. The early recognition and control of the allergic processes should lower the incidence of the development of hyperplastic and polypoid changes with secondary infection. The incidence of hyperplastic and polypoid changes in patients with nasal and sinal allergy is between 20 and 30 per cent, depending upon the type of cases under consideration, the highest incidence occurring in patients with perennial nasal allergy, hay fever and asthma. These are the patients who represent the largest percentage of the group which is subjected to surgical interference.

With proper allergic management in the early stages of the disease, it is evident that the incidence of marked pathologic changes could be very materially reduced, and, consequently, the number of patients requiring some type of surgical operation.

Among otolaryngologists there exists a great deal of difference of opinion as to the type of operation (radical or conservative) most effective in the treatment of both infective and allergic involvement of the maxillary sinus. Hempstead emphasizes the importance of preoperative studies including the use of the antroscope. By this means the presence of polyps, cysts and tumors, as well as the condition of the lining mucosa, often can be determined.

Hempstead's observations were based upon a study of 385 patients treated by the conservative type of intranasal operation. It is noteworthy that in 22.5 per cent of the cases the infection was caused by dental caries. It is noteworthy that polyps were not found in cases of infection of dental origin. Among the 385 patients treated by the conservative method it was necessary to perform the Caldwell-Luc operation upon only two of them. In both instances the antrum was filled with polyps. Hempstead refers to the report of Tucker, who, in 1928, reported that in a series of 673 patients with chronic maxillary sinusitis the intranasal operation was performed with success in all but six, in whom the radical type of operation was necessary. It is noteworthy that in the nine patients in whom polyps could be seen at operation, the polyps could not be observed later.

Hempstead further states that when infection complicates an allergic process, a dry antrum cannot be obtained until the allergic condition has been controlled. For postoperative treatment, dry suction is recommended instead of irrigations with aqueous solutions.

It was finally concluded that the intranasal window operation has many advantages, the most important of which are: reaction is much less severe than with the radical operation; there is a minimum of injury to the lining mucosa; polypoid and badly infected mucosae have been seen to return to normal after the establishment of drainage and ventilation. It is significant that among 1,634 cases collected from the literature by Hempstead, a good result was obtained in 97 per cent of the cases treated by the establishment of an intranasal antrum window.

In evaluating the end-results of intranasal operation on the ethmoid, frontal and sphenoid sinuses, Faulkner emphasizes that a satisfactory outcome is usually dependent upon the performance of a complete operation. Although many of the

cases of hyperplastic and polypoid disease require surgical interference, allergy has not as yet been given due consideration as the most important part of the treatment. The general belief has prevailed that failure in these cases is usually the result of poor or incomplete surgical operations. While this is certainly true in the treatment of the pure cases of suppurative sinusitis, it is not necessarily true in the allergic cases. Often the conservative removal of nasal polyps and hyperplastic tissue is all that is necessary in most cases in which adequate allergic management has been instituted.

In discussing the subject of end-results of external operations on the maxillary sinus, Salinger states that conclusions as to the effectiveness of this operation must be based on the relation of the local findings to the symptoms, a consideration of the patient as a whole, and a determination of the degree of care and skill with which previous conservative treatment has been applied. He advises the Caldwell-Luc operation only when there exists within the antrum a degree of pathologic change which is beyond the hope of repair by any means short of complete removal and when the pathologic change so diagnosed is the cause of the symptoms for which the patient seeks relief. The pathologic changes to which reference has just been made are divided into two groups: The one associated with various degrees of local symptoms of which the patient is aware; and the second, more or less silent or occult but associated with manifestations of disorders elsewhere in the body. The first group, according to Salinger, is usually characterized by the symptoms of nasal discharge, obstruction to breathing, headaches and frequent colds. The patient may have been treated by various minor procedures, such as antral lavage, tamponade, removal of polyps and other intranasal operations, and the process has manifested cycles of comparative relief between attacks, according to the weather and the patient's general health.

Salinger further points out that examination during an attack reveals a purulent or mucopurulent discharge, with or without polyps, thickened, red lateral pharyngeal bands, cloudiness of the antra, usually more marked on one side, and marked obscurity of the shadow on a Roentgenogram. Between attacks the symptoms vary from comparative normalcy within the nasal passages to the presence of mucopurulent discharge, polyps and a red or glazed pharynx. A persistent cloudiness of the antrum by X-ray and transillumination is

considered a constant finding. Even though irrigation yields little or no secretion, with the above Roentgenologic findings, Salinger feels that the conclusion that the lining membrane of the sinus is not normal is inescapable. Salinger gives the greatest consideration to the appearance of a thickened, irregular membrane at a time when the patient has the fewest subjective symptoms and a minimum of objective findings. In other words, he states, if the sinus looks bad when the patient feels best, there can be no doubt that a chronic unresolved process is present which will yield to nothing less than radical extirpation. Salinger concludes by stating that he has never been disappointed in the operation when the preoperative diagnosis was based on sound facts and careful study and when possible allergic factors had been thoroughly investigated and taken care of.

From the standpoint of clinical symptoms, course and physical findings, it is evident that in cases of this type we are dealing mostly with allergy. In every instance it is important in the beginning to determine whether the process is a pure infection, an allergy or an allergy complicated by an acute, subacute or chronic infection. There should be no difficulty in making this distinction if the clinical history, physical findings and Roentgenologic findings are correlated with the cytologic and bacteriologic findings. The cytologic determination alone is of indispensable value in making an accurate diagnosis. Without it, no one can be 100 per cent accurate in diagnosis, especially in determining the presence of acute, subacute or chronic complicating infection. As Salinger points out, the Roentgenologic findings are most significant during a period of quiescence of symptoms. The persistence of a cloudy antrum at this time does not, in my opinion, however, justify a radical operation in every instance. If the process is allergic and there is no significant infection as determined by cytologic and bacteriologic examinations, operation may not be indicated unless there has been no improvement with adequate allergic management. In any event, satisfactory end-results of surgical interference of all types of allergic disease of the sinuses are more dependent upon adequate allergic management than upon properly performed operations. Allergic control of symptoms and pathologic changes may eliminate the necessity of surgical interference entirely or may so ameliorate the process that conservative procedures are adequate and radical interference is not indicated.

In his discussion of the end-results of external operations on the frontal, ethmoid and sphenoid sinuses, Arbuckle states, "Rhinologists have seen the rise of popularity of surgical treatment of sinal disease on the basis that infection was the underlying cause in all cases. During all this time, in a certain number of cases, relief was not obtained by such treatment. Then they found that many such conditions are not of infectious origin but are allergic. Accordingly, the popularity of operative treatment has decreased almost to the exclusion of certain types of surgical intervention in favor of antiallergic treatment and, occasionally, endocrine treatment."

Arbuckle further calls attention to the rapidly increasing general belief that allergy is a most important factor in the cause of the complaint in well over half of all persons suffering with symptoms of sinal disturbance and that when the condition is correctly diagnosed and properly treated, operation is contraindicated except in instances of infection of a type for the relief of which surgical intervention is indicated; therefore, it is emphasized that the necessity of differential diagnosis between infectious sinusitis and allergic sinusitis is obvious. Arbuckle also emphasized the importance of cytologic examination of secretions in all cases and the necessity of instituting adequate allergic study and care.

In Arbuckle's experience he has noted that, as a rule, when allergic sinuses are operated upon, symptoms disappear for from six weeks to six months, after which the allergic symptoms recur when the patient is exposed to allergens to which he is sensitive. This is in agreement with other observers. He also remarks that he has observed a number of patients with nasal polyps in the early stage of development in whom the polyps disappeared with allergic management and remained absent until this growth was restimulated by an acute infection or an allergic exacerbation. On the other hand, attention is called to the fact that polypoid tissue which has become fibrotic does not disappear with such treatment.

ALLERGY AND SINUSITIS IN CHILDREN.

Nasal polyposis is almost exclusively a disease of adult life, except the choanal form, which not infrequently occurs in children. Laff[19] reports an unusual case of deforming and recurring polyps in an asthmatic child. He also reviews the literature on this subject but finds comparatively few reports.

The case reported by Laff was that of a child, male, age 15 years, who had had nasal symptoms and asthma since the age of 7 years. The polyps were first removed at the age of 9 years. When the patient was 15 years old, Laff removed the polyps again and performed a bilateral ethmoidectomy.

Nasal polyps in children are extremely rare before the age of puberty. On several occasions we have noted edematous thickening of the lower edge of the middle turbinate and in the middle meatus in children under the age of 10 years, but we have not observed a case of definite nasal polyps before puberty. We have, however, noted several instances of polyps in children at the ages of from 13 to 16 years.

Barnett and Carnahan[20] emphasize that allergy is a common cause of rhinitis in children, whether acute or chronic, seasonal or perennial, recurrent or constant, and that it is often unrecognized. A great deal of importance is placed upon the value of cytologic examinations of nasal secretions in diagnosis. Allergic control is vital if necessary associated surgical procedures are to be of benefit. Barnett and Carnahan point out that removal of infected tonsils and adenoids may aggravate symptoms in a child with uncontrolled allergy.

Crooks[21] presents his observations on a series of 100 cases of sinusitis in children. In 24 patients the tonsils and adenoids were removed because of the presence of mucopus in the antra. Further observations of these patients showed that after six months 16 still had the sinal condition. The following symptoms were most commonly listed: nasal or postnasal discharge in 84 cases, frequent colds in 83, cough in 82, mouth breathing in 62, headache in 44, and otitis media in 44. Diagnosis was made by transillumination, Roentgenograms and direct puncture. The predominating bacteria recovered from the sinuses were pneumococci and streptococci. When the antrum did not clear up after six irrigations, Crooks did an intransal antrotomy. Of the 100 patients, 52 were cured, 32 improved, and 16 unchanged.

The majority of the papers which appear in the literature on sinal disease in children are of this type, in which allergy is not considered as an etiological factor. Even if an attempt were made to exclude cases of this type, it could not be done accurately without cytologic studies of the nasal and sinus secretions. It is probable that the group of cases reported by

Crooks consisted of both allergic and infectious or combined types.

Birdsall[22] reports his observations on a series of cases of nasal sinusitis in children occurring over a period of two years at the Paddington Green Children's Hospital in London. The ages of the patients ranged from 2 to 13 years: 36 were boys, and 44 were girls. Sixty of the 80 patients were between the ages of 5 and 9 years, inclusive.

Birdsall states that the onset was usually insidious and the symptoms were found to occur in the following incidence: nasal obstruction, 39; cough, 33; frequent colds, 32; rhinorrhea, 21; pain, 14; throat symptoms, 12; anorexia, eight; otorrhea, seven; bronchitis, six; listlessness, five; postnasal discharge, four; asthma, four; and epistaxis, three.

The tonsils and adenoids had previously been removed in 19, or half, of the patients with nasal obstruction. In 35 of these 39 cases, nasal obstruction was associated with rhinorrhea. Cough was an outstanding symptom in 33 cases. Twenty-seven patients had nasal discharge. In the remaining six cases, cough was attributed to bronchitis. Two had asthma. Of the 32 patients with frequent colds, three had bronchitis. Of the remaining 29, 14 had previously had a tonsillectomy. Twenty-one patients had definite rhinorrhea.

In discussing etiology, Birdsall states that, in children, sinusitis is insidious in its onset. Only one case of acute sinusitis was observed among the 80 cases. The duration of symptoms varied from one week to nine years, the average being two and one-half years. In 13 instances some specific illness preceded the onset of symptoms. In seven of these the sinusitis followed whooping cough. It is noteworthy that 33 of the children in this series had undergone tonsillectomy without benefit. The average period following tonsillectomy and preceding observation was three years, during which the symptoms had gradually been increasing in severity.

Mucopus was found in the noses in 42 patients. In 36 of these, the prominent symptoms were cough, frequent colds or rhinorrhea. Fourteen showed opacity of one or both antra upon Roentgenographic examination. In 11, mucopus was found upon antrum lavage.

Thirty-four patients showed significant changes in the nasal mucosa, such as pallor, redness or pseudoatrophy. Birdsall

states that in chronic infection the mucosa becomes pale and edematous. Mucopus was noted in the nasopharynx in 27 cases. Enlarged tonsils were noted in 12 patients. In two they were removed. In 10 the condition of the tonsils improved with treatment of the sinuses. Five patients had a dermatitis of the lip and anterior nares.

In 37 cases an X-ray examination of the sinuses showed changes in the antra in 35 instances. In 22 patients the ethmoids were also involved. Bilateral involvement of the antra was noted in 24 cases.

The results of treatment were as follows: Of the 80 patients, 59 received adequate treatment. Fifty-two of the 59 patients were cured, 34 after a course of displacement therapy with 0.5 per cent ephedrine solution in 1 per cent saline; 13 after combined treatment by displacement and antrum lavage. Five were subjected to antrotomy and four were improved.

This report has been reviewed in detail in order to offer some constructive criticism of the diagnosis and treatment of sinusitis in children. In the management of nasal and sinal diseases in children, accurate diagnosis cannot be established and adequate treatment instituted unless allergy is considered as an etiological factor. Sinal disease in children must be considered as purely allergic, infectious or a combination of allergy and acute, subacute or chronic infection. In our experience 95 per cent of the chronic sinal diseases in children are primarily of allergic origin. The differentiation of the above types of sinus disease can be readily accomplished by correlating the clinical history and the physical and X-ray examinations with the cytology and bacteriology of the nasal and sinal secretions. Accurate differentiation usually can be made on the basis of the cytologic examination alone, a pure eosinophilia denoting an uncomplicated allergic process, and a neutrophilia or a combination of an eosinophilia and a neutrophilia signifying various degrees and types of complicating infection.

A survey of the clinical history and physical and X-ray findings in Birdsall's group of cases suggests a very high incidence of allergic disease. No cytologic or bacteriologic studies were reported. It is, therefore, impossible to determine the exact incidence of allergy and infection in this series.

In the management of frequent colds, sinusitis, bronchitis and recurrent pneumonia, Hansel and Chang[23] emphasize consideration of allergy as a possible etiologic factor. In an investigation of 200 children who were seen routinely for the consideration of removal of tonsils and adenoids, a definite diagnosis of allergy was established in 26, or 13 per cent. Six of the patients had hay fever. It was further stressed that these cases of respiratory allergy may be overlooked unless an adequate history, physical examination and cytologic studies are carried out in each instance. Removal of the tonsils and adenoids in allergic children should not be performed during a hay fever season, and the indications for operation should be the same as in nonallergic children. The tonsils and adenoids should not be removed with the idea of alleviating allergic symptoms.

MISCELLANEOUS TREATMENT.

In 44 cases of various allergic conditions, such as asthma, urticaria and pollen asthma, Boyer[24] investigated the use of propadrine hydrochloride. Four patients stated that the propadrine was inferior to other forms of medication, especially ephedrine. Five felt that propadrine was equally efficacious to previous medication, and 35 patients reported their greatest symptomatic improvement occurred from this drug. Clinically, bronchospasm and rhinitis were relieved. There were no side reactions so commonly encountered in the administration of ephedrine. Marked relief, therefore, was obtained without the usual nervousness and insomnia which may follow ephedrine. It was not found necessary to administer sedatives with propadrine hydrochloride.

In the local treatment of nasal allergy the preparations containing silver salts are often employed. Prolonged use of silver salts may result in the production of general argyria. Bryant[25] reports the case of a patient who was treated daily for three months with a 10 per cent solution of mild protein silver in the form of Dowling packs for the relief of symptoms indicative of chronic ethmoiditis. Upon examination the entire nasopharynx looked as though it had been sprayed with soot, and the nose showed that every millimetre of the mucosa was almost black. The only other areas of pigmentation were the finger nails and the conjunctiva of the lower lids. After several months following the discontinuation of

the treatment with the silver protein, the nasal membranes had lightened considerably, indicating that absorption does take place directly from the site of application despite the rather widespread opinion that the silver is absorbed only from the intestinal tract. Bryant suggests that reduction and absorption must occur at the site of application.

Of 26 carefully selected and studied cases of vasomotor rhinitis, Prickman[26] noted definite relief from the use of histaminase in nine, or 34 per cent. In four instances the results were questionable; in the remaining 13 no relief whatsoever occurred. In patients who obtained relief, the administration of the drug had to be continued, as it did not appear to produce desensitization.

Wilson-Pepper and Royle[27] report a case in which menorrhagia had existed for two years and spasmodic rhinorrhea of considerable severity for 18 months. Upon injection of the first dose of progesterone the nasal symptoms immediately subsided and did not reappear for several weeks. It is suggested that progesterone warrants further consideration for treatment of rhinorrhea.

At the University of Minnesota, Diehl[28] and his co-workers conducted a three-year study of cold vaccines used on students. Nasal allergy and sinal infections were excluded. The conclusions may be summarized as follows: The group receiving vaccine subcutaneously experienced an average of 25 per cent fewer colds per person than did the control group. The difference is considered of no importance, however, because a reduction of 25 per cent is not sufficiently great to justify the time and expense in giving the treatment. The group which received a polyvalent vaccine orally experienced just as many colds as the control group. Although the data presented are not conclusive, there is no evidence in this study either that the vaccines reduce the complications of colds or that the condition of the nose and throat is related to the frequency of colds in the cold-susceptible group.

The controlled study of cold vaccines by Hanser and Hanser[29] was conducted on a series of 369 students at the University of Michigan. The following conclusions were drawn: Over 66 per cent of subjects who received placebos stated that they had fewer colds than during the year preceding the experiment. Of the persons who received vaccine

intradermally, over 64 per cent considered themselves similarly improved. Of those who received the vaccine subcutaneously, 80 per cent reported fewer colds than during the preceding year. Although the proportion of subjects reporting improvement was greatest in the group in which the vaccine was given subcutaneously, the percentage of difference between the three groups was considered within the limits of possible error.

HEADACHE.

Gittins[30] points out that in most instances of headache only subjective symptoms are present, with no objective evidence to further a diagnosis. Transient disturbances of vasomotor origin in the brain, meninges, ganglia or nerve sheaths, whether spoken of as migrainous, allergic or functional upsets, are responsible, he states, for the symptom complex in most instances.

In discussing the various symptom complexes associated with headache, Gittins emphasizes that real pathologic changes in the nose, sinuses, brain or other part of the head cannot be responsible for such systematic reproduction of similar explosive phenomena over long periods, with intervening periods of good health.

Among other conditions which may cause headache, the possibility of allergy is also emphasized by Gittins. He further states that "spontaneous relief, temporary or permanent, of periodic headache or neuralgia with associated symptoms of vasomotor or allergic origin is more common than is similar relief from the combination of all treatments and operations in the otolaryngologic field and all other branches of medical practice."

ESOPHAGEAL AND BRONCHOSCOPIC ASPECTS.

Withers[31] reports a very interesting case of gastrointestinal allergy in which there was involvement of the esophagus. The patient complained of periodic attacks of difficulty in swallowing, pain, bloating and belching. The patient also had nasal allergy. At first the attacks were mild and occurred irregularly at five- to seven-day intervals. Upon avoidance of the causative foods the patient remained symptom-free for more than two weeks. Several foods were found to reproduce symp-

toms. The severity of the attacks could be markedly relieved by the ingestion of 0.025 gm. of ephedrine. It was not definitely determined whether the obstructive symptoms were caused by spasm or by edema of the esophageal mucosa.

Although benign and malignant tumors of the trachea are not particularly common, on account of the symptoms produced they may simulate bronchial asthma. Olsen[32] reports 16 cases of carcinoma of the trachea encountered at the Mayo Clinic since 1921. It is pointed out that the symptoms of carcinoma of the trachea are caused chiefly by the action of a group of mechanical factors. The most common and the most urgent complaint is shortness of breath. The type of dyspnea produced is obstructive in type and should be easily recognized because of the presence of stridor. The dyspnea is frequently paroxysmal and occurs most often at night or when the patient lies down. Cough is present in nearly all instances. At the onset it is usually nonproductive, but eventually it is accompanied by expectoration of mucopurulent sputum. Emphysema and atelectasis may also be present. Olsen further emphasizes that in most instances a diagnosis of asthma is made at some stage of the disease. In the differential diagnosis a great deal of significance should be placed upon the cytology of the bronchial secretions. In the absence of eosinophiles a diagnostic laryngoscopy and bronchoscopy certainly should be performed at once.

CHEILITIS

Hecht and Rappaport[33] report a very interesting case of cheilitis with fixed drug eruption and gastrointestinal allergy from the eosin dye of lipstick. After a clinical investigation and patch testing, it was found that the symptoms were caused by the dye in the lipstick, tetrabromofluorescein. Upon avoidance of this preparation, the cheilitis and dermatitis of the face subsided. It is especially noteworthy that the gastrointestinal symptoms also subsided. It was finally concluded that the general use of lipsticks containing tetrabromofluorescein or similar dyes by American women may explain some cases of gastrointestinal disturbances of the nature of spastic colitis or mucous colitis.

ALLERGY OF THE EYE AND EAR.

Upon a careful search of the literature, Parkhurst and Lukens[34] could find reports of only three cases of dermatitis

caused by butyn. They add a fourth case of a patient, age 49 years, in which 2 per cent butyn was used in the eye as a local anesthetic. The next day the patient had a marked swelling and itching of both eyelids on the right side. The following day there was a more severe dermatitis of the lids, with vesiculation and edema; the eye was swollen shut. An erythematous vesicular streak, about 5 mm. wide, extended down the cheek to the chin, apparently following the path along which the solution had run. A positive patch test was noted 24 hours after application of butyn to the skin of the arm. The opinion was expressed that such instances of sensitivity to butyn occur more frequently than the paucity of reports would seem to indicate. A case of sensitivity to butyn of a similar nature came under our observation only recently. The skin of the eyelids on both sides were markedly involved with a dermatitis. Eyedrops containing butyn had been used. A positive patch test was demonstrated.

Annenberg[35] reports six cases in which corneal lesions followed the cutting of weeds. Five of the patients complained of pain, redness, itching and the sensation of a foreign body in the eyes. The palpebral and bulbar conjunctivae showed redness but no corneal involvement. From two to four days later, however, grayish areas of infiltration appeared in the cornea. These reactions lasted several days. Pigweed was found to be the offending factor. One of the patients had another manifestation of allergy. Treatment consisted of the daily injection of foreign protein.

Sjögren[36] reports a case in which the patient, after contact with a certain kind of wood, developed an attack of unilateral nasal obstruction and contemporaneous edema of the eyelid, chemosis of the conjunctiva, transitory myopia of 3.75 D. in association with shallowing of the anterior chamber and a considerable diminution of intraocular pressure. The emptying of the anterior chamber consequently caused a projection of the iris-lens diaphragm.

The patient reported by Granstrom and Nylen,[37] a woman, age 56 years, had had for several years repeated attacks of Ménière's disease and also attacks of palpebral edema of the angioneurotic type, accompanied by iritis-like attacks of short duration. This latter was considered as "an intraocular edema of Quincke," and the attacks of Ménière's disease were

thought to be an analogous process in the labyrinth. All the symptoms were considered allergic in nature, although the offending allergen was not found. The examination of the function of the labyrinth and cochlea showed normal findings between attacks. During the attacks, vertigo, rotary-horizontal nystagmus on change of position of the head, and a marked reduction of hearing in the left ear developed.

Jones[38] discusses the occurrence of an allergic type of otitis media. In one instance a child was found sensitive to chocolate, nuts and wheat. The attack was induced by the ingestion of nuts. In a patient with chronic allergic labyrinthitis, the symptoms disappeared upon the elimination of milk.

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STUDIES ON THE ANATOMY AND PHYSIOLOGY OF THE TONGUE.*

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INTRODUCTION.

Throughout the literature on the production of speech sounds one finds such statements as:

"From time immemorial the tongue has been recognized as the chief constituent of the mechanism of articulation.[1]

Teachers of speech and speech pathologists working with articulatory defects of speech, *i.e.*, oral inactivities, oral inaccuracies or sound substitution, have gone on the assumption that the degree of a pupil's or a patient's difficulty depended largely upon the degree of malformation or malfunction in the muscles of the tongue. Exercises have been given to strengthen these muscles. More accurate positions have been striven for.

Many children develop an unintelligible, slovenly mumbling of sounds in their effort to speak. Upon investigation it is usually discovered that there is very little activity in the tongue muscles. The child is apparently unable to raise the tongue for the production of the anterior linguapalatal sounds, l, t, d, n and their consonant combinations. There may be a physical defect known as tongue-tie . . . or there may be no physical defect but only a functional inactivity of the tongue due to a poor speech environment or poor speech training. As this condition is due to sluggish tongue muscles, plenty of tongue exercises should be given to correct it.[2]

In the last two years cases have been referred to the Speech Department of Central Institute for the Deaf which substantiate the opinion that proper functioning of the muscles of the tongue is necessary for the production of articulate speech sounds. There is, for example, the case of a young man, age 20 years, who has been a private pupil since Oct. 1, 1937. He has a tongue whose intrinsic muscles are completely inactive. His speech, when he entered Central Institute, was unintelligible. He could read very little. He had finished only the third grade in school because of his speech defect. His general health is good, he has good teeth and normal occlusion.

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His hearing is normal. He has always understood all that was said to him. He was given a performance test in March, 1939. His I.Q. is 89.

The action of J.'s tongue muscles has improved very little with training. He cannot lift the tip of it to his teeth ridge or move it to either side of his mouth. His articulation has not made appreciable improvement. There seems to be a positive correlation between the tongue muscle spasticity and speech intelligibility. The lack of movement in the tongue seems to prevent articulate speech.

To cite another case, G., who has been a day pupil in the Speech Department of Central Institute for the Deaf since September, 1936, has a tongue that is almost inactive. When he entered school he had no speech. He now has speech, but it is almost unintelligible. His general health is good, he has normal hearing, normal eyesight, and understands all that is said to him. He has an I.Q. of 91. Q. has a very short memory span and poor manual dexterity. He cannot lift the tip of his tongue back of his upper teeth or move it from side to side. There seems to be again a positive correlation between this child's lack of tongue movement and the unintelligibility of his speech.

Two brothers were recently brought into the Speech Clinic, one age 6 years, the other age 8 years, whose cases are interesting as an observation on tongue muscle function. The 6-year-old's frenum was cut for tongue-tie, but in the opinion of the laryngologist who examined the child's tongue, it was not cut back far enough. He has some free tip but not as much as is normal. He cannot lift it back of his upper teeth or move it from side to side. His speech is very difficult to understand.

The tongue of the 8-year-old boy has a frenum that binds the entire apex of the tongue to the floor of the mouth. It has no free tip whatever. The speech in this case is very easily understood. The boy has learned to lift the back of his tongue to his hard palate rather than lifting the tip to his teeth ridge when making l, t, d and n. His voice quality is very nasal because he is producing his sounds posteriorly rather than anteriorly.

Three other cases have been observed that definitely do not bear out the opinion that articulate speech sounds are dependent upon the proper functioning of the tongue muscles.

PLATE I.

Fig. 1. Showing preoperative condition.

Fig. 2. Showing preoperative condition.

Presented by courtesy of
Dr. E. L. Keyes, St. Louis.

Two of these were cases in which the entire tongue had been amputated at the hyoid bone. One operation was performed some 20 years ago. The speech of this patient is easily understood. The other tongue was operated eight years ago. The surgeon who removed it says:

> The patient was seen when he was 49 years of age, with a very bad carcinoma of the left side of the tongue. In July, 1931, I did a complete left-sided neck dissection and complete removal of the tongue. The neck wound was left open and he was fed with a feeding tube for several weeks. He had an almost uninterrupted recovery and the oral fistula from the mouth out onto the neck was closed some weeks later.
>
> "Since this time the patient has made a remarkable rehabilitation of his life, he is able to carry on his work as a plumber, is easily understood by anyone and completely understood over the telephone. He states that he has the same sense of taste that he always had and requires the same seasoning in his food. He had been issued three insurance policies, and at this date, April 26, 1939, he is apparently in perfect health with no sign of local or distant lesion.[3]

A third case was observed in which the posterior third of the tongue remains on the left side. The surgeon who operated the case reported:

> S., age 61 years at that time, consulted me on Jan. 15, 1937. Patient stated that he had sores on his tongue for about a year and a growth on his tongue for three months which was painful when he chewed. Examination at that time showed a large ulcer over the anterior third of the dorsum of the tongue measuring 1.7 x 1.5 cm., involving chiefly the midportion and extending somewhat to the right. The margins were raised and pearly and the growth was papillary. There was a second similar area on the right margin of the tongue, somewhat smaller. . . . On April 10, 1937, I amputated the tongue at Jewish Hospital. I removed all of the right half of the tongue and the anterior and middle thirds on the left, purposely leaving a portion of the posterior third of the left. Diagnosis by Dr. S. H. Gray, of the Jewish Hospital Laboratory, on microscopic examination was carcinoma of the tongue. The patient made an uneventful convalescence from the operation and since that time has shown no evidence of recurrence.[4]

On Feb. 18, 1939, Keyes demonstrated Mr. S.'s ability to speak with so small a residuum of tongue tissue before a meeting of The Progressive Oral Advocates, held in the Auditorium of Central Institute for the Deaf. S. was readily understood in the back of the room. His only defective speech elements were voiced and unvoiced "th."

These three cases of tongue amputation present a speech situation that is completely contrary to the long accepted opinion that the tongue is the all-important factor in the formation of consonant sounds. Two of the cases cited have no tongues at all, the other only a small residuum of tongue tissue, yet they speak fluently and articulately. Is the tongue —

PLATE II.

Fig. 3. Showing the postoperative condition. Tongue drawn back.

Fig. 4. Showing the postoperative condition. Tongue protruded.

Presented by courtesy of
Dr. E. L. Keyes, St. Louis.

the facility with which it moves, its size, its shape, so important in articulation as has been thought?

Little has been written in the field of speech or of medicine on the anatomy and physiology of the tongue that would apply to an explanation of this apparently paradoxical situation: articulate speech in cases without tongues; inarticulate speech in cases with inactive tongues. This investigation is an attempt to answer the question of just how large a part must the tongue play in the articulation of speech sounds.

HISTORY.

Medical history contains more cases that deal with unusual speech adaptations than does the literature in the field of speech. Apparently there have been other such cases as the three cases of tongue amputation studied at Central Institute. A case was reported by Jussieu in 1718 which appears in the Historie de l'Academie des Science of congenital absence of the tongue, or Aglossia. This condition is thought to be due to failure of union of the projection from the inferior maxillary arch with that from the second pharyngeal arch. Jussieu made particular mention of the speech of the patient cited:

> A girl of Allenteio in Portugal was seen at the age of 15 years. She had no tongue, but there was a nipple-like projection in the floor of the mouth, three to four lines high. This was muscular and could be moved. Of the five functions of the tongue, speech was so clear that no one could suspect the deformity; certain words were difficult, and she moved her head in pronouncing them. Certain consonants in the French alphabet were pronounced with difficulty, c, f, g, l, n, r, s, t, x. y, z; none of the vowels was included. Taste was apparently perfect. Mastication was difficult as she could not clear the food from the cheeks and gums and had to use her finger to do this. Swallowing of food was easy if taken in small quantities; solids were negotiated, but the swallowing of the last part was difficult and she had to make it very fluid. She could spit with the aid of the mylohyoid muscle.[5]

Prinz and Greenbaum in commenting upon Jussieu's report say:

> A small nodular elevation in the middle of the floor of the mouth took the place of the normal tongue. This nodule was movable to some extent and assisted in speech that was not affected. . . . Loss of the tongue following some grave disease such as syphilis or carcinoma is not quite so rare as congenital absence of the tongue. Here also the chief difficulty is encountered in chewing and swallowing, while speech is usually not impaired.[5]

Kettner reported another case of aglossia with further error in development in *Deutsche Medizinische Wochenschrift*

in 1907, in which he, too, calls attention to a lack of impairment in speech:

> A boy with a cleft palate and a defect in the development of the hands and feet. A band stretched between the tongue and the buccopharyngeal membrane; this was divided. At the age of 4 years the tongue appeared to be absent, but could be seen with a mirror as a three-cornered swelling far back in the mouth. He could pronounce the vowels and most of the consonants with the exception of "d" and "t."[7]

A divided tongue is occasionally seen as the result of accident or disease. According to medical opinion, a congenital cleft of tongue does not interfere with speech. A case was cited by Bywater:

> A man, age 35 years, had a tongue separated into two parts by a central depression extending backward for a quarter of an inch from the tip. From this depression a median groove (which was deeper near the bifid tip) extended backward on the dorsum of the tongue and also beneath it. The tongue was of normal size and healthy in appearance. The frenum was normal. The patient has had the deformity all his life.[8]

Another congenital malformation spoken of in the literature that does not apparently interfere with speech are supernumerary tongues. Seitz, in the New York Medical Record for 1902, reported:

> A Jewish boy, age 5 years, who had no family history of deformity, had beneath his tongue a rudimentary organ one inch long and a little broader than long. It arose where the tongue normally joined the floor of the mouth. The anterior end was blunt; the frenum was three-eighths of an inch thick. The smaller moved with the larger tongue and gave no trouble in talking.[9]

Gould and Pyle, in "Anomalies and Curiosities of Medicine," quote a case of the Rev. Henry Wharton, Chaplain to Archbishop Sancroft, who, in his journal in the seventeenth century, says that he was born with two tongues and so passed through life. One tongue gradually atrophied. Apparently his speech was not affected.

The cases cited from the history of medicine do not, in any sense, prove that the functioning of the muscles of the tongue is not necessary in the production of articulate speech. They do, however, serve as a basis for asking the question: "With what muscles do tongueless people speak?" And further, "How is this speech adaptation made?"

THE COMPARATIVE ANATOMY OF THE TONGUE.

Most writers have always considered the prime function of the tongue in man to be that of articulation. Yet animals as

far down the evolutionary scale as some amphibians, the frog, for example, possess tongues with extrinsic muscles attached to a rudimentary hyoid bone, and intrinsic muscles innervated by the hypoglossal nerve, making the organ very comparable to that in man. Needless to say, frogs' tongues do not function in articulation. Victor Negus, in his book on "The Mechanics of the Larynx," makes a like observation concerning the larynx when he says:

> The larynx is generally known as the organ of voice and yet it takes but a moment's reflection to observe that thousands of species which have a larynx never, or practically never, make use of voice.[1]

This study will present a compilation of some of the literature on the evolution of the tongue from fish through to the tongue found in man. It has been proved that articulate speech can be achieved without a tongue. Consequently, this study will not commence with an "articulatory bias" but will trace the organ through the lower species and attempt to correlate the anatomical and physiological likenesses and differences with the tongue of man.

Little was found concerning the tongue of fish, other than that it is a very rudimentary organ. It consists of a fold of mucous membrane covering the basihyoid, which in higher vertebrates serves as the attachment for many lingual muscles.

Taste is the only special sense not enclosed in a mesodermic capsule. The lowest form of the sense of taste is a nerve eminence in the integument of the lower animals. In bony fish these nerve eminences are scattered over the whole body and especially in the fins, the lip-folds and the mouth. In lung-fish they are found only in the mouth, pharynx and nose, and are supplied by the facial, the glossopharyngeal and the pneumogastric nerves.

In the amphibian tongue there is greater range in structure than there is in that of the fish. In some, the tongue is almost absent; in others it contains intrinsic muscles and is innervated by the hypoglossal nerve. The tongue of the frog has both intrinsic and extrinsic muscles. The extrinsic muscles present are: *1.* the hyoglossus, and *2.* the genioglossus. The extrinsic muscles are the transversus and the longitudinalis. The longitudinalis lies immediately beneath the mucosa on the dorsum of the tongue and is formed from the hyoglos-

sus and the genioglossus. The transversus in frogs is not attached to the septum linguae. The tongue of the frog can be thrown out of the mouth with rapidity and with a hinge-like motion, bringing the food farther into the food channel than is possible with the tongue action found in other amphibians. Protrusion is accomplished by the action of the genioglossi, and its retraction by the action of the hypoglossi.

The tongue of crocodiles, turtles and tortoises is stronger than that in the frog but is less mobile. It is attached to the floor of the mouth.

In amphibians the sense of taste is in the papillae of the oral and the pharyngeal mucous membranes and on the jaws and tongue. The latter are the first to have taste function. The taste organs in the frog are flat discs and occur in hundreds on the tongue and soft palate.

The tongue of reptiles has parts found in the amphibian tongue together with a median growth, the tuberculum impar, a median lingual swelling in the floor of the mouth. The musculature is the same as that in amphibians with the addition of the verticalis and the longitudinalis inferior. In the lower part of the tongue lies the osentoglossum, which in higher mammals becomes the lyssa (present in a dog's tongue). The tongue lies in a sheath below the floor of the pharynx and is attached to the hyoid system, which provides a firm support from which it can move. The tongue in most reptiles is used for protrusion and the capture of prey, but it is designed in such a way that its function ceases when it is drawn into the mouth. The trigeminal nerve appears in the reptilian tongue along with the hypoglossal and the glossopharyngeal.

In birds, the tongue has lost its lateral parts and with them the trigeminal nerve. It contains no intrinsic musculature. Birds' tongues vary greatly in form. They are scarcely an organ of taste as they are served by only a few filaments of the glossopharyngeal nerve and most of the taste buds are in other parts of the buccal cavity.

> In birds the distribution of the gustatory organ is apparently dependent on the size and form of the tongue: when the latter is narrow, they are situated on the thin, glandular mucous membrane of the lower beak; and when it is broad, on that of the upper beak or of the pharynx. The arrangement is irregular and their number varies greatly in different groups, being greatest in parrots, in which their structure resembles that of mammals.[11]

A bird's tongue is controlled by the usual hyoidean muscles plus four other pairs: the ceratohyoideus muscle, which passes from the thyrohyal and to the urohyal and is subservient to the lateral movements of the tongue. A singular pair of muscles, the ceratotrachealis, arises from the trachea, twists four times around it and then passes forward, to be inserted into the base of the thyrohyals. It is the principal retractor of the bird tongue.

Parrots have the largest tongues among birds, due to fat vessels and glands rather than to any special muscular development.

THE EVOLUTION OF THE MAMMALIAN TONGUE.

It is generally accepted that the evolutionary history of the mammal tongue must be traced back to a group of cynodont reptiles. There are no fossil tongues, so that the characteristics must be deduced from a wide view of the vertebrates. Sonntag suggests that the first tongues must have been a simple plate, traversed near its lower surface by an os entoglossum. The musculature must have been simple. The mucous membrane probably had gland cells and nerve endings that were tactile in function. The papillae must not have been prominent and were mainly conical. The mammalian tongue was evolved out of the reptilian tongue by an increase in its musculature and papillary structure. The increased musculature, principally the addition of the genioglossus and the lingualis inferior, thickened the tongue. The os entoglossum and the lower part of the reptilian tongue became the lytta and the sublingua. These structures proceeded to disappear in various orders. Some orders retained both, others retained the sublingua, or the lytta, others eliminated both. The lytta became absorbed into the undersurface of the tongue. In many orders there is no trace, as a rule, of the sublingua in an adult, but its occurrence in the fetus and the very occasional appearance of remnants in young animals shows a condition that once existed.

Mammals differ from the lower vertebrates in mastication, in insalivation and in their licking power. The movements in these actions have led to the emergence of the mammalian tongue and to its further development after it evolves.

GENERAL CHARACTERISTICS OF MAMMALIAN TONGUES.

Mammalian tongues, as a class, differ greatly in shape. They may be conical, oval, spatulate, triangular or veriform.

The greatest width is usually between the attachments of the two faucial pillars; in spatulate tongues it is usually farther forward. The length is measured from the apex to the mid-point of the glossoepiglottidean fold. The tongue is divided into three regions anatomically; the oral part, which is measured from the apex to the median circumvallate papillae; the pharyngeal part that is measured from the median circumvallate papillae to the glossoepiglottic fold; the part from the mucous fold of the tongue to the epiglottis is sometimes referred to as the third zone.

The apex of the mammalian tongue may be found, flat or pointed, entire or notched. It may be small, narrow and deep, or wide and shallow. It always bears papillae, though they are not always visible. When the tongue is protruded in most animals the apex is seen. The elephant is an exception. The apex is bound down to the floor of the mouth and a piece of the anterior part of the dorsum takes its place.

A median fissure may or may not be present in the mammal tongue. It may be continuous or interrupted. There may only be a separation between two lateral masses of conical papillae or it may indent the mucous membrane. The median fissure may be restricted to the front middle and back of the tongue; it may be narrow throughout or widened from before backward. The inferior surface of the tongue, like the dorsum, may possess a median fissure or ridge. It is narrow and deep, or broad and shallow. It may end abruptly or open into a triangular depression into which the frenum passes. In the kangaroo there is a firm, hard median ridge passing back from the apex to the frenum.

Transverse ridges and fissure that appear in tongue specimens may be real or artificial. Artificial ones are those that appear in material after it has been in a fixative. One must examine fresh material to ascertain the presence of true transverse fissures. They are regular and symmetrical; complete or incomplete; straight or curved, with their convexities running forward.

The arrangement of the papillae on mammalian tongues varies. They are of three kinds: circumvallate papillae, fun-

giform papillae and conical papillae. At the sides are fissures and intervening laminae, termed foliate papillae or lateral organs. These latter are not always present. The circumvallate vary in number from one to 12. They are the largest and the fewest of the papillae and are usually arranged in a single row. Papillae may be above, flush with or below the dorsum of the tongue. The protruding type is commonest. They may be round, oval or keeled. Their surface may be smooth, polished and glistening, or granular.

The tongue of the Badger has an interesting vallate region. It is colored brown. The papillae appear to be beneath the surface and shine through the mucous membrane, which looks as if it were composed of transparent mosaics.[22]

The fungiform papillae on the tongues of mammals are more numerous than the circumvallate. They are bright red in color and vary in appearance, number and arrangement. They are small, globular bodies lying in depressions of mucous membrane. They are sessile or pedunculated. The fungiforms lie close to the attachment of the faucial pillars on the dorsum. In the dog, the fungiform papillae are difficult to see.

The conical papillae are the most numerous of all the papillae. They vary more in distribution, size and form than do any of the others. In some primates they are restricted to the oral region, but in most mammals they appear on both the oral and pharyngeal regions. The papillae on the two parts sometimes differ histologically. They are ordinarily found in clusters behind the apex and dotted over the whole dorsum.

The functions of the papillae are many. Taste is not one of them. Papillae are tactile, retentive or mechanical, the function differing in different animals. They are assisted by the shape of the mouth, the nature and strength of the lingual muscles and the ridges and tubercles on the soft palate.

On the inferior surface of the tongue are found: the papillary border, the mesial furrow or ridge, the frenum and the openings of the sublingual glands. The papillary border may go all around or be interrupted at the apex. The frenum extends from the posterior end of the free part of the inferior surface of the tongue to the floor of the mouth. It originates from the plane surface of the tongue or from the bottom of the triangular depression. It varies greatly in length.

On the undersurface of the tongue and sometimes within its substance is the remains of the glossohyal cartilage known

as the lytta. It varies in situation and character. It is developed especially in the dog and aids in lapping. It is very elastic.

THE TONGUE OF THE CATACEA (WHALE).

The tongue of the whale is the simplest of all mammal tongues. It is almost comparable to the tongue of fish and crocodiles. This is thought to be because all mammals but whales masticate. Lower vertebrates do not masticate. Consequently, there is no reason for the whale tongue having developed beyond the lower vertebrate level.

In the toothed whale the tongue is firm, hard and muscular; the upper surface feels like parchment. In the Baleen whale the tongue is soft and has a great amount of fat or oil that separates the mucous membrane from the muscles. Some authors have likened it to a sack of blubber. The tongues of the former variety are more mobile than those of the latter. In the one the tongue is an organ of prehension; in the other it is a passive organ; the food simply flows into the open mouth.

The type of tongue is due to the method of feeding. When the whale feeds it swims with considerable velocity under the water with its mouth wide open; the water enters by the forepart but is poured out again at the sides and the food is entangled and sifted by the whalebone that doesnot allow anything to escape.[12]

The mobility of the tongues of toothed whales varies. In one order it is great because the free part extends back to the fourth interdental arch. In another the apex is bound to the mandibular symphisis by a fold of mucosa. The edges of the apex are free. In a third order the tip is mobile from side to side. In all orders the tongue is more mobile in the newborn animal than in the adult. The shape of the tongue is comparable to that of most other mammals.

The apex of the whale tongue varies considerably in different orders. In some it is full and rounded, in others it is not so full and has warty processes and growths protruding from the epithelium. In still others, it has a smooth surface and is pointed. In most cases there are no median or dorsal sulci present.

The inferior surface of the tongue, in many species, is corrugated and may rest on a kind of a cushion formed by

mucosa in the floor of the mouth. The degree of corrugation found varies with the age of the animal. In one order, a thick fold surrounds the tongue below the apex. The whale tongue, while being very deficient in muscular development, has a more highly developed glandular system than any other mam-

PLATE II.

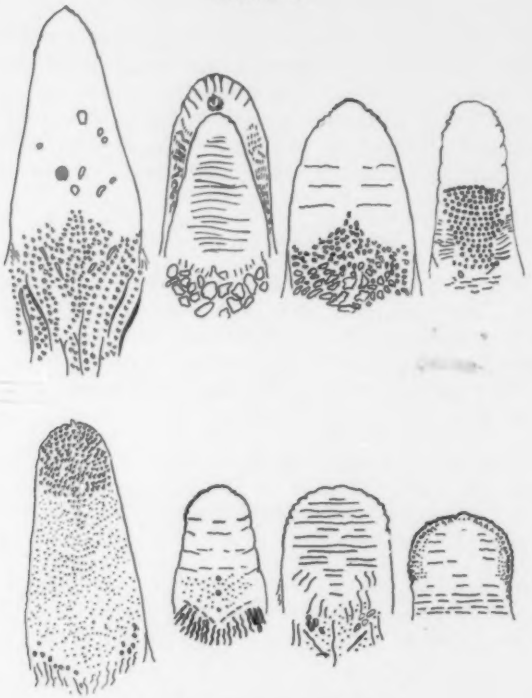

Fig. 3. The tongues of Whales.

Sonntag, Chas. F.: Proc. of Zool. Soc. of London, Vol. II, Figs. 26, 27, 28, 29, pp. 641-646, 1922.

mal. The orifices of innumerable oil glands appear on the inferior surface. They vary greatly from one order to another in their extent and prominence.

In most orders of whales the papillae are scanty or absent altogether. Those that do appear are almost always tactile or mechanical. The sense of taste is absent or very slight. It is

more deficient than in any other mammalian order. It is because the gustatory and mobile functions of the whale tongue are so deficient that it is the lowest mammalian tongue in the evolutionary scale. Authorities differ as to whether it is the result of lack of evolvement or of degeneration.

THE TONGUE OF THE RODENTS.

The tongue of the rodents is a great deal more complicated than that of any of the whales. The rodents, as an order, are very diversified but their tongues do not differ very widely. They are all very thick and have short frena. The tongue fills the mouth closely and is, in many cases, divided into a low anterior part and a raised posterior intermolar eminence.

THE SQUIRREL'S TONGUE.

The tongue of the common ground squirrel is long, narrow, thick and tapering. The free part is moderately long. The oral part comprises more than the anterior two-thirds of the dorsum. On the squirrel's tongue there is no intermolar eminence. The apex is round and devoid of a notch, with thick lateral borders.

There are three circumvallate papillae arranged in a triangle on the posterior part of the dorsum. The tongue is richly supplied with taste-buds whose nerve supply has been traced into the epithelium.

On the inferior surface there are the openings of many glands. There are no traces of frenal lamellae, sublingua, plicae fimbriatae or lytta.

THE BEAVER'S TONGUE.

The tongue of the beaver is relatively shorter, broader and thinner than that in the squirrel. There is a low, broad intermolar eminence extending across the tongue in its posterior part. There are three circumvallate papillae, just as in the squirrel, and numerous fungiform papillae. The entire base of the tongue is covered with glands, both mucous and serous. The apical gland of Nuhn, which is present all the way up the evolutionary scale, first appears in the tongue of the beaver.

THE TONGUE OF THE DORMOUSE.

The dormouse has a tongue that is small, narrow and thick. The oral part makes up more than two-thirds of the dorsum. The apex is rounded and has no notch or prominent papillae. On the inferior surface the frenum is short and has no frenal lamellae. But there is a very well developed sublingua in the form of a soft, flat plate extending back from the apex to the

PLATE III. THE TONGUES OF RODENTS.

Fig. 4. The tongues of Squirrels.

Fig. 5. (A and B) The tongue of the Beaver. (C) The tongue of the Dormouse.

Sonntag, Chas. F.: Proc. Zool. So. of London, Vol. II, Figs. 31 and 32, p. 728, 1924.

frenum. The dormouse is the only rodent that has a sublingua.

THE TONGUES OF RATS, MICE AND MUSKRATS.

The tongues in these little animals are long, narrow and thick. Their oral parts are long, while the base is short. The apex is thick, rounded and devoid of a notch. No prominent

papillae of any kind appear on the apex. There is an intermolar eminence in most species.

Most rats, mice and muskrats have a single, median circumvallate papilla. It is usually of considerable size and forms an obstruction in small tongues. This single papilla is rounded or flattened and covered with secondary papillae. Taste buds have been observed on the upper surface of the

PLATE IV. THE TONGUES OF RODENTS (Continued).

Fig. 6. The tongues of Mice and Moles.

Fig. 7. Rat-like animals from South America.

Sonntag, Chas. F.: Proc. Zool. Soc. of London, Vol. II, Figs. 33 and 34, pp. 730 and 733, 1924.

secondary papillae in many species. They receive their nerve supply from a large encapsulated ganglion within the papilla. The fungiform papillae are scanty. The conical are numerous, minute and close together.

On the inferior surface of the tongue there is no trace of the sublingua, plica fimbriatae, frenal lamellae lytta or apical gland of Nuhn.

THE TONGUES OF MOLES.

A mole's tongue is long, narrow and thick. On the anterior surface there is a median dorsal sulcus; and on the posterior surface a flat intermolar eminence. Three circumvallate papillae are present rather than just the one found on the

PLATE V. THE TONGUES OF RODENTS (Concluded).

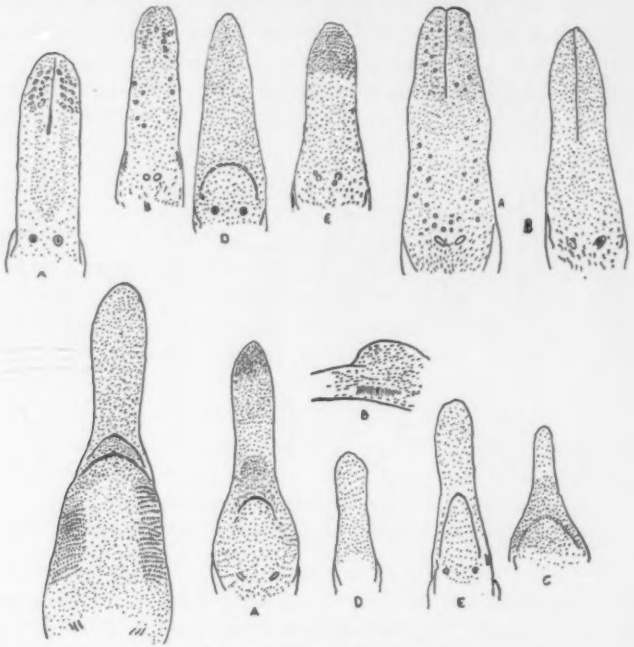

Fig. 8. The tongues of Porcupines.

(A) Cavy, (C) Chinchilla, (D) Aquatic Cavy, (E) Rabbit.

Sonntag, Chas. F.: Proc. Zool. Soc. of London, Vol. II, Figs. 35, 36, 37, 38, pp. 725-755, 1924.

tongue of rats and mice. The fungiform papillae are scanty, while the conical are numerous, simple and very close together.

THE PORCUPINE'S TONGUE.

In all types of porcupine the tongue is long, narrow and thick. It has a rounded apex that may have a notch. In this

rodent two circumvallate papillae are found on the posterior part of the dorsum. In some species there is a flat, horny plate on the anterior surface.

THE TONGUE OF THE GUINEA PIG.

The largest rodent tongue is found in the guinea pig. It is long, narrow and thick in the anterior half, but is wide and thick at the base because the intermolar eminence is encircled by a transverse sulcus. The apex is rounded and has no

PLATE VI. THE TONGUES OF THE EDENTATA.

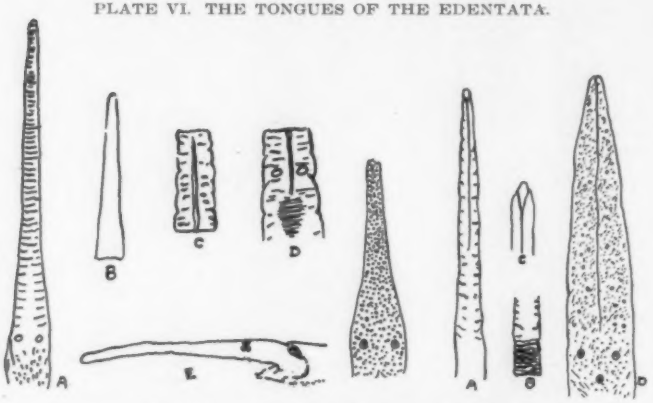

Fig. 9. The tongue of the Great Anteater.

Sonntag, Chas. F.: Proc. Zool. Soc. of London, Vol. II, Figs. 50, 51, 52, pp. 516-525, 1923.

notch or prominent papillae. The lateral borders of the guinea pig are massive. The intermolar eminence is covered with innumerable papillae. The most peculiar characteristic of this rodent tongue is that it has no circumvallate papilla at all. At least one appears in all other mammals.

THE RABBIT'S TONGUE.

The tongue of the rabbit is spatulate in shape. The intermolar eminence is long, prominent and pointed. Unlike the intermolar eminence on the tongue of the guinea pig, the one on the rabbit's tongue is narrower than the tongue itself and consequently does not add to the width of the tongue at the base. Two circumvallate papillae appear on this rodent

tongue. The fungiforms, as on the tongues of all other rodents, are scanty and minute. The conical papillae are also very small.

THE TONGUES OF THE EDENTATA.

Anteaters and sloths comprise the order edentata. Their tongues are characterized by extrinsic muscles with a high degree of specialization, and glands and gustatory organs with a slight or moderate degree of development. Their mobility is greater than that of all other mammalian tongues. The mobility is designed for prehension and for mechanical action on food.

The tongue is long, in some, and not flattened anteriorly; in some other species the tongue is long, flat and triangular; and in a third type it is short, with the usual mammalian form. The apex in the order edentata bears peculiar globular or pointed organs; in different species it has a varied form. In some it appears as a globular expansion of the whole apex, in others it takes the form of a button-like structure attached to the centre. Some authors say that these are sense organs, others that they are definitely gustatory in function.

In some species of edentata there are two sharp processes with their ends directed forward and inward beneath the apex. They receive prolongations of the lingual musculature. Their function is probably to capture and grip food.

In the scaly anteater there is a median dorsal sulcus in the form of a wide, shallow groove on the flattened anterior part of the tongue. Another species has a fine groove running along the greater part of the dorsum.

In edentata with long, veriform, protrusible tongues, there are sheaths into which the tongue can be retracted. In the scaly anteater it is in the form of a corrugated, cuff-like sheath.

All species of edentata have two circumvallate papillae. They are circular, with the apex of the cone attached to the tongue. The surface of the papillae is smooth or granular. Close examination shows that when the surface appears to be granular it indicates the presence of secondary papillae. The long axes of the taste buds seem to run downward and

outward toward the fossae which pass under the base of the cone-like papillae.

The lytta is present in the manis or scaly anteater. It is as large as it is in many carnivora.

The frenum is short in all edentata.

THE TONGUES OF THE INSECTIVORA.

In all insectivora, moles, hedgehogs and like animals, the tongue is very simple. It is long and narrow, and the free part is of considerable extent. The dorsum usually thickens gradually from before backwards, but its thickness is never greater than its length. The oral part of the dorsum is long, the pharyngeal part short, in all species.

The apex in the tongue of the insectivora varies in shape. In some it is rounded, in others it is truncated, and in still another species it is pointed. It is usually devoid of a notch. The lateral borders are rounded.

There is no median dorsal sulcus on the tongue of the insectivora, but transverse ridges and sulci may be present or may be produced by the impression of the palatal rugae on the tongue. In all species there are two or three large circumvallate papillae arranged in a triangle.

The frenum is short in all species. In some the lytta is well developed. It is composed of muscle fibres, fat and fibrillar tissue but no cartilaginous elements are present.

THE TONGUES OF CARNIVORA (BEASTS OF PREY)

FELIDAE (CATS).

The tongues of these beasts, the lion, the tiger, the jaguar, the wildcat, the hyena and others, are long and comparatively narrow. The tongues of the lion and the tiger are wider than the others. They thicken progressively from before back. The free part is never very thick.

The apex is rounded in all species, but usually devoid of a notch. It has small, conical and fungiform papillae on its surface but they do not stand up very prominently. There is no large cluster of papillae containing taste-buds, as is found on the tongue of the primates.

The base of the tongue is usually close to the epiglottis, with the exception of the lion and the jaguar. In these two animals there is a long stretch of mucous membrane between the base of the tongue and the epiglottis. This large space is associated with the roaring habits of these animals.

PLATE VII. THE TONGUES OF CATS.

Fig. 10.

The papillae in many species have thick, sharp or round, horny sheaths that have a mechanical action on the food.

CYNOIDEA (DOGS, WOLVES, FOXES).

The general form of the tongue is the same in this group of carnivora as in the cats. The number and kind of papillae vary.

The dog tongue is wide and thin in front and very mobile. It is deep red in color, with a dorsum that has a wide median groove. In the

inferior part of the tip there is a fusiform cord composed of fibrous tissue, muscular tissue and fat. In the large dog it may be two inches long. It is called the lyssa or sublingua and is supposed to correspond to the last vestige of the tongue of lower vertebrates which has been replaced by the more highly developed tongue. A remnant can be seen in the human tongue just after birth.[14]

In the dog and the common fox, serous glands surround the circumvallate papillae and mucous glands cover the base of the tongue. The frenum is well marked in all species. The median glossoepiglottic fold may run forward for a considerable distance onto the pharyngeal part of the tongue. The lytta is well marked in all cynoidea.

THE TONGUES OF THE UNGULATA.

The tongues of the hoofed mammals, or ungulata, are long, comparatively narrow and very mobile. The tongue in the rhinoceros is an exception, being broad and flat. The tongue of the giraffe has the greatest mechanical power of any mammal.

The giraffe's tongue is very extensible, flexible and deeply pigmented. He is able to twine his tongue around small objects. The muscles are the same as in other mammals; the difference is in the great extent of the organ anterior to the insertion of the genioglossus. The intrinsic muscles are less closely interwoven, which allows for more separated action.[15]

The apex of the tongue in the hoofed animals may be truncated, pointed or rounded. The anterior part is flat and very mobile in most species. Posterior to the apex is the intermolar eminence, found also in the tongue of the little rodents, which serves to raise the food to the molar teeth. The intermolar eminence is entire in all species but the rhinoceros, where it is cleft. In the horse it is low and flat, but well marked. Ungulata have well developed salivary glands but few lingual glands. The tongue of the giraffe has more papillae than any other mammal.

The frenum in the ungulata is always present and permits the tongue to be very mobile, with the exception of the elephant, whose apex is bound down to the floor of the mouth. The tongue of the hog has a double frenum.

THE TONGUES OF THE ANTHROPOID APES – THE CHIMPANZEE.

Of the three tongues examined, one was fresh, one was from the Society's prosectorium, and the other from the museum of the Royal College of Surgeons. The fresh specimen was a female from Southwest Africa.[16]

The measurements of the fresh tongue were: Total length, 9.1 cm.; the length from the apex to the anterior median circumvallate papilla was 6.1 cm.; from that papilla to the epiglottis, 3 cm. The width between the attachments of the faucial pillars was 4.5 cm.; the width of the apex was 3 cm.; the thickness in the region of the anteromedian vallate papilla was 3.5 cm.; the thickness of the apex was 3 cm. The tongue of the chimpanzee, taking these measurements into consideration, is long and narrow. The width does not decrease greatly from the base to the apex. The elongated form of the tongue is said to be due to the shape of the mouth.

PLATE VIII. THE TONGUES OF THE ANTHROPOIDS.

Fig. 15. Fig. 16.

Fig. 15. The Chimpanzee. Fig. 16. The Gorilla.

Sonntag, Chas. F.: Proc. Zool. Soc. of London, Figs. 1 and 3, pp. 3 and 5, 1921.

The antero-median circumvallate papilla stands a short way from the top of an elevation whence the dorsum slopes toward the base and the apex. The declivity is greater toward the base. The chimpanzee in this respect is pre-eminent among anthropoids. The degree of slope varies in individuals. The apex of all anthropoid tongues is blunt and may or may not have a notch. In the three tongues examined by Sonntag only the fresh specimen had a notch. The apex is roughened by conical papillae, and tuberculated by large, prominent fungiform papillae. The size of the latter type varies in individual tongues. They are always numerous.

The mesial sulcus may be present on the dorsal and inferior surfaces. It is usually irregular. On the base of the

tongue the median row of circumvallate papillae is situated on a depressed row of mucosa which is bounded by large papillae and lymphoid nodules. There are always eight circumvallate papillae arranged in the form of a "V." They have granulated surfaces.

The base of the tongue contains much lymphoid tissue, which gives the surface a lobulated appearance. The lymphoid nodules vary in size; the larger ones have a small, central pit.

PLATE IX. THE TONGUES OF THE ANTHROPOIDS (Continued).

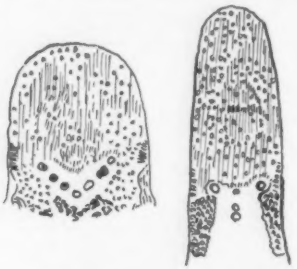

Fig. 17. Fig. 18.

Fig. 17. Simia Satyrus (Orang-outang). Fig. 18. The Siamang.
Ibid., Plate IX, Figs. 4 and 5, pp. 15 and 18.

The inferior surface of the tongue of the chimpanzee presents a mesial sulcus, the papillary border, the frenum and the sublingual fold. The frenum is short and thick. It runs from the sublingual fold to the undersurface of the tongue.

THE TONGUE OF THE GORILLA.

There is not such a great disproportion between the length of the tongue and its width in the tongue of the gorilla as there is in that of the chimpanzee. It is comparatively broad, appearing almost rectangular. It slopes gently from the circumvallate papillary region to the apex, and more steeply to the epiglottis.

The apex of the tongue of the gorilla is square-cut and has no mesial notch. It bears conical and fungiform papillae in thick clusters. The medial sulci are present on the dorsal and inferior surfaces. On the dorsum it is wide and shallow, and terminates in a pit at the anteromedian papilla. There is no

median sulcus on the base of the tongue. The median inferior sulcus begins in front at the posterior edge of the papillary zone and runs back, widening as it goes, and terminates in a triangular pit into which the frenum passes. On the anterior two-thirds, several transverse sulci are present.

THE ORANG-OUTANG.

The tongue of the orang-outang resembles man's in the proportion of its length to its width and in certain structural peculiarities. Preserved specimens were examined from the Royal College of Surgeons.[17]

The apex of the orang-outang tongue is round and has no mesial notch. It has conical and fungiform papillae on its surface. Both forms are small. The lateral borders are massive, with both conical and fungiform papillae. The dorsum has no median or transverse sulcus.

Papillae cover most of the surface of the dorsum, and a bounding zone on the inferior surface. The fungiforms are very small. A double row forms a prominent arch around the anterior extremity of the frenum. Conical papillae are a marked feature on the anterior two-thirds of the dorsum. They increase in size from before backward, and from without inward. They are arranged in clusters, transverse rows and oblique chains. The base of the tongue is devoid of long, conical papallae present in other anthropoids. In this respect the orang's tongue resembles man's.

The orang agrees with man and differs from all other anthropoids in the possession of the Apical Gland of Nuhn, or the anterior lingual gland.

Finally, on the inferior surface of the tongue on either side of the frenulum, near the apex, are the anterior lingual glands. In man, each is about 15 mm. in length and is composed of a group of racemose glands, with about five very small ducts opening on the surface between the anterior portions of the plicae fimbriatae. The anterior lingual glands are deeply placed and are covered not only with mucosa but also by longitudinal muscle fibres. The gland is of mixed type, though chiefly mucous.[18]

The tongue of the orang-outang resembles the tongue of man in several respects:

1. It is like in general proportions.
2. It has a rounded apex.
3. The circumvallate papillae are arranged in a "V" pattern.
4. It has no long, conical papillae on its base.
5. It has a well marked frenum.
6. The orang's tongue possesses a sublingual fold.
7. It possesses the Apical Gland of Nuhn.

THE SIAMANG.

The tongue of the siamang is long and narrow. The distance between the anteromedian vallate papillae and the epiglottis is greater than in other anthropoids. The apex is rounded and devoid of a notch, with its surface covered with conical and fungiform papillae. The lateral borders are full and rounded. Papillae are present on the apex, the lateral borders, the entire anterior two-thirds of the dorsum and the sides of the posterior one-third. On the posterior one-third of the dorsum there is a large central area, devoid of papillae.

PLATE X. THE TONGUES OF ANTHROPOIDS (Concluded).

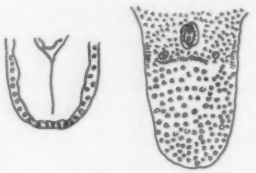

Fig. 19. The Hylobates Hoolock.

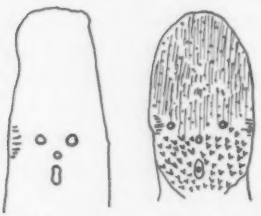

Fig. 20. The White-Handed Gibbon.

Ibid., Plate IX, Figs. 6 and 8, p. 21.

There are five circumvallate papillae arranged in a "V." There are no lymphoid nodules on the base. The frenum is short and runs from the floor of the mouth to a triangular depression on the inferior surface.

THE HOOLOCK GIBBON.

The tongue of the Hoolock gibbon is short, compact and rough. It tapers from the base to the apex. The tongue of the Hoolock gibbon has no nonpapillary region at the base. There are four circumvallate papillae on this tongue. The frenum is of moderate length.

THE BORNEAN GIBBON.

A fresh specimen was examined; a female. The tongue measured 6.5 cm. in length, and 2.8 cm. in width from the attachment of the faucial pillars. The tongue was long, narrow and pigmented. The dorsum in front of the vallate papillae is bluish-black in color and glistening bluish-black papillae appear prominently. Their color is darker than the dorsum itself. The dorsum behind the vallate papillae is white. The inferior surface has a central unpigmented surface shaped like a spearhead.[19]

A median sulcus is present in the tongue of the Hoolock gibbon, both on the dorsum and on the inferior surface. The inferior surface is surrounded by a papillary border that is rough to the touch. There are three circumvallate papillae arranged in a triangle. At the base of the tongue there are large, conical papillae. Their surfaces are granular. The frenum in the tongue of the Bornean gibbon is short and thick.

THE TONGUE OF MAN.

The previous section dealing with anthropoids leads to a detailed discussion of the tongue of man. Anatomists consider that Merkel's work, "Anatomie und Physiologie des Menschlichen Stimm-und Sprach-Organs," includes the most authoritative account yet presented of the anatomy and physiology of the tongue of man.*

Merkel,[21] in his treatise on the tongue of man, dismisses the nerves as being unimportant from the point of view of phonetics; however, from the standpoint of comparative anatomy, the nerves, together with the glands and the papillae will be briefly outlined.

The sensory nerves of the tongue are the lingual, which is a branch of the mandibular, serving the anterior two-thirds of the tongue with sensory fibres; the chorda tympani, a branch of the facial which runs in the same sheath with the lingual, is regarded as the nerve of taste in the anterior two-thirds of the tongue; and the lingual branch of the glossopharyngeal that sends sensory fibres to the base and the sides of the tongue. The superior laryngeal nerve sends some fine filaments to the root of the tongue near the epiglottis. The motor nerve of the tongue is the hypoglossal.

The papillae are thickly distributed over the anterior two-thirds of the dorsum. The circumvallate papillae are of large

*For completion of this thesis this chapter of anatomical details has been translated into English and is added to the original ms.

size and range in number from eight to 12. They are found in the same position as in lower mammalian tongues and are in a "V" shape.

The fungiforms are more numerous. They are found chiefly on the sides and on the apex, and rather sparingly on the dorsum.

The filiforms or conical papillae cover the anterior two-thirds of the tongue. They are very minute and are arranged

PLATE XI.

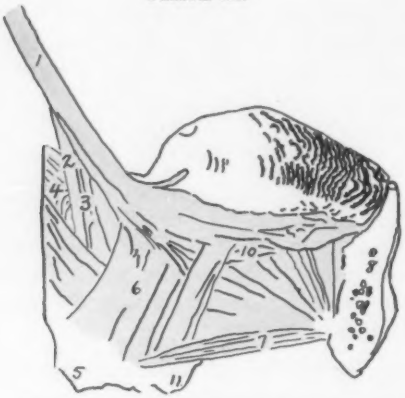

Fig. 21. The extrinsic musculature of the human tongue.

1. Styloglossus.
2. Stylopharyngeus.
3. Stylohyoid ligament.
4. Constrictor pharyngeus.
5. Great cornu of the hyoid.
6. Hyoglossus.
7. Geniohyoideus.
8. Mandible.
9. Genioglossus.
10. Longitudinalis inferior.
11. Body of the hyoid.

in lines parallel with the rows of vallate papillae except at the apex, where their direction is transverse.

The simple papillae are similar to those of the skin and cover the whole of the mucous membrane as well as the larger papillae.

The glands of the tongue are both mucous and serous. The mucous glands are found on the apex, the sides and particularly on the back, behind the vallate papillae. The anterior lingual glands require special notice. They are found on the

undersurface of the apex, one on either side of the frenum, where they are covered with muscle fibres. This gland is present only in the tongue of the orang-outang and in man.

DISSECTION TECHNIQUE.

Three nine-months fetal heads were dissected in the laboratory of Central Institute for the Deaf. The following technique was used:

Starting with a curved incision through the skin on the right side of the face, it was carried from in front of the ear near the articulation of the mandible and extended to

PLATE XII.

Fig. 22. The intrinsic musculature of the human tongue. Sagittal section.

1. Longitudinalis inferior.
2. Longitudinalis superior.
3. Transversus.
4. Genioglossus.
5. geniohyoideus.
6. Body of the Hyoid.
7. Epiglottis.

Spalteholz, Werner: Hand Atlas of Human Anatomy. J. B. Lippincott and Co., Phila., Fig. 582, p. 507; Fig. 584, p. 508, 1930.

the outer corner of the mouth. A second incision was made downward in the midline from the lower lip to the symphysis of the mandible and was carried below the chin to the hyoid. Skin flaps were reflected from the sagittal incision, exposing structures below the tongue forming the floor of the mouth. The superficial fascia, from the right side below the chin, was removed, exposing the anterior belly of the digastricus. Slightly in front and medially, a smooth bundle of muscle fibres was encountered coming from beneath the digastricus and ending in the median raphe. This proved to be the medial portion of the mylohyoid muscle.

The anterior belly of the digastricus was now reflected back by cutting it away from its attachment to the mandible.

The mylohyoid muscle was thus exposed as the thin sheet of muscular fibres described above. It arises from the mylohyoid line upon the medial surface of the body of the mandible by an origin which extends from the symphysis of the mandible to the hyoid. The two mylohyoid muscles stretch across from one side of the body of the mandible to the other above and in front of the hyoid. They form a sling for the structures of the floor of the mouth.

PLATE XIII.

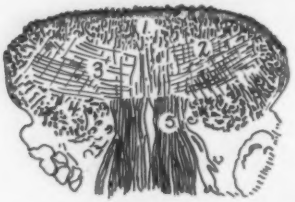

Fig. 23. Cross-section through the body of the tongue.

1. Longitudinalis inferior.
2. Longitudinalis superior.
3. Transversus.
4. Glossoglossus.
5. Geniohyoideus.
6. Body of the hyoid.
7. Epiglottis.

Fig. 24. Cross-section through the apex of the tongue.

Ibid., Plate XII, Fig. 585, p. 509; Fig. 586, p. 509.

The mandible was then removed with the tongue from the remaining portions of the head. This was done by cutting through the capsule of the temporo-mandibular joint, the external and internal pterygoid muscles and through the temporomandibular ligament. The orifice of the mouth was widened by cutting back the corners of the lips in order to prevent injury to the tongue.

The mandible was split at the symphysis and the tongue removed from its anterior and lateral attachments. The dorsum of the fetal tongue was observed to be much smoother to the touch than is the adult tongue. The papillary structures

are there, but in a lower stage of development than in the adult tongue. From this observation it was concluded that the papillae develop as the diet of the individual changes. The plica fimbriatae and the sublingua are more highly devel-

PLATE XIV. THE NERVES AND ARTERIES OF THE TONGUE.

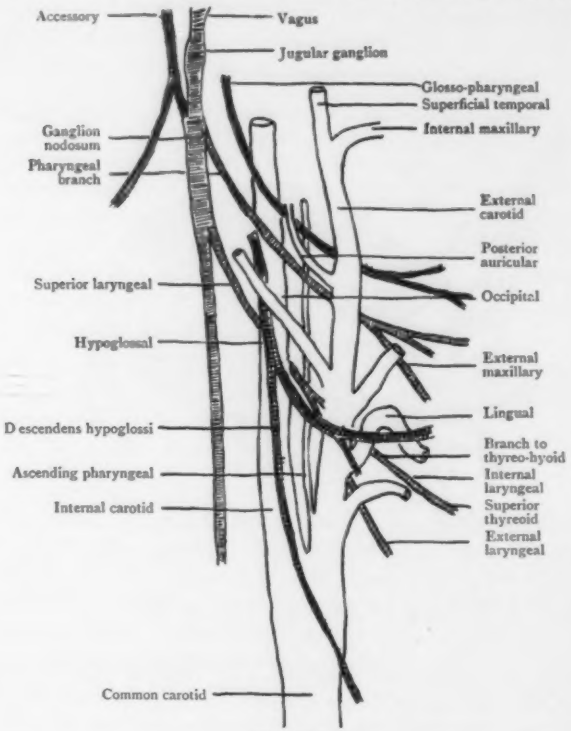

Fig. 25.

oped in the infant tongue than in that of the adult. They appear to degenerate as the child matures.

A study of the extrinsic and intrinsic musculature was now made. The extrinsic muscles were identifiable as the styloglossus, the glossopalatinus, the glossopharyngeus and the genioglossus. Between the fibres of the styloglossus and the genioglossus the inferior aspect of part of the longitudinalis inferior could be seen.

The next step was to remove the extrinsic muscles, as far as possible, preparatory to making microscopic sections of the intrinsic musculature.

The dorsum of the tongue was divided longitudinally at the lingual septum. The material was put into: *1.* 80 per cent alcohol; *2.* 90 per cent alcohol; *3.* 100 per cent alcohol; *4.* zylol; *5.* paraffin.

PLATE XV.

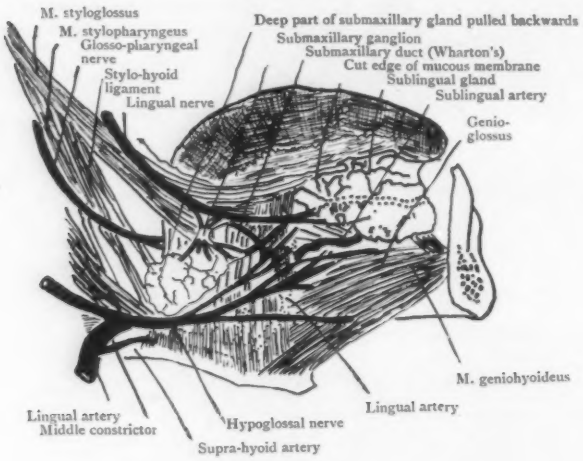

Fig. 26.

Robinson, Arthur: Cunningham's Manual of Practical Anatomy. Wm. Wood and Co., N. Y., Fig. 75, p. 201; Fig. 71, p. 191, 1930.

When the tissue was thoroughly infiltrated with paraffin, it was placed in a metal form and hot paraffin poured around it. When the block was thoroughly hardened it was cut with a microtome into slices six microns in thickness. After the slides were cut they were stained with hemotoxylin.

In studying the fetal tongue by means of the dissections, it was found that the fetal tongue does not differ from the adult tongue in muscular structure. The only point of difference is on the dorsum. The fetal tongue is smooth to the touch because of a deficiency in papillary development. The adult tongue is rough, with countless papillae rising above the level of the epithelium.

CONCLUSIONS.

The tongue, throughout the animal kingdom, is different from other organs of special sense, such as the eye or the ear, in that it serves not one function but several. The tongue in the lower vertebrates has as its most specialized function that of prehension. The tongue of the frog can be thrown in and out with a hinge-like action as the frog goes after food. A snake's tongue can be protruded from the mouth with great rapidity in the act of prehension.

In the lowest animal of the mammalian order, the whale, the tongue is almost a useless organ. It has no prehensile power of function in mastication because of the manner in which the animal eats. Further along in the mammalian order the tongue again assumes as its principal function that of prehension. The anteater's tongue is long, sharp and easily protrusible; the tongue of the giraffe is long and has very facile movement. It can be twined around small bits of food, such as leaves and twigs.

The function of the tongue as an organ of deglutition and mastication has developed with the change in the manner in which various animal groups eat and the variety of diet which they eat. These functions are most highly developed in the primates.

The sense of taste has developed from nerve eminences all over the bodies of bony fish to highly developed taste buds on the tongue and oral cavities of all mammals but the whale. In man, the sense of taste is most highly developed because of the enormous number of papillae rising above the level of the epithelium on the dorsum of the tongue, in the buccal cavity, in the fundus of the pharynx and on the inside of the lower lip.

The musculature of the tongue varies very little from one order to another, with the exception of the musculature of the whale tongue, which, again, through disuse, is almost nonexistent. The tongues of the rodents have minute muscles that are the same in structure as those in the tongues of the larger animals. Sonntag[22] goes so far as to say that if one were given two tongues, one of a man, the other of an orang-outang, one would have difficulty in differentiating between them because they are so similar in muscle structure, in size, in shape and in papillary arrangement.

The foregoing discussion on the phylogenetic development of the tongue indicates that its prime functions are prehension, mastication and deglutition. Articulation becomes an added function in man. Judging from the fact that speech is the least impaired of all of the functions in cases of tongue amputation, it was concluded that teachers of speech may have been too empirical about the exact functioning of the muscles of the tongue in speech being a necessity in the production of aurally acceptable speech. The patients studied have difficulty in deglutition and in mastication, but they can and do speak without a tongue.

After dissecting three nine-months fetal tongues, it was observed that the fetal tongue does not differ from the adult tongue in musculature. Its one point of difference is the epithelium of the dorsum of the tongue. In the fetal one, the dorsum is smooth to the touch, with undeveloped papillary structures.

This investigation will be continued in order to determine what musculature replaces that of the tongue in producing the articulate speech of those without tongues.

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INHERENT ACCURACY OF A SERIES OF REPEATED CLINICAL AUDIOGRAMS.*

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Abington, Pa.

Much has been said concerning the superiority of audiometers as instruments for the measurement of hearing but little has been published concerning quantitative comparison of repeated audiograms. Ciocco[1] compared results of first and second examinations of Washington, D. C., school children; however, a three-year interval between audiograms leaves something to be desired if the data are to be truly indicative of the usual run of audiograms made in an otologist's office.

The investigation reported herein was undertaken on a long series of audiograms in an endeavor to obtain a quantitative determination of errors in hearing measurements on hard-of-hearing patients and the probable relationship between the errors on hard-of-hearing and normal individuals. A total of 297 audiograms made on 17 patients in the Otological Research Laboratory of the Abington Memorial Hospital have been used in the investigation. Patients whose histories and examinations showed chronic conditions likely to cause undue variations in hearing were excluded from the study, and no patients were included on whom therapy of any sort was practiced. Patients with an extreme tinnitus, those treated with thyroid extract and those to whom cold vaccine was given were excluded.

As already stated, none of these 17 patients was given any form of active treatment during the period represented by the audiograms. No audiograms were used if taken in the course of an upper respiratory infection. All of the patients had some type of conductive deafness. Thirteen were women, four were men. The salient points in the history and clinical examination follow.

Seven patients gave a history of some familial deafness. In the family histories no specific type of deafness was recorded.

*From the Otological Research Laboratory, Abington Memorial Hospital, Abington, Pa.

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The age of onset varied from 4 to 34 years, with an average of 19 years. The duration of the hearing impairment ranged again from 4 to 34 years, with an average of 8.6 years.

In addition to the deafness, 10 of the 17 patients complained of an annoying tinnitus.

Before presenting for examination, all but one of the patients had had tonsillectomy and adenoidectomy performed. Six had had some nasal operation.

Eleven of the group had been diagnosed at some time as otosclerotic.

Sixteen had been subjected to routine Eustachian dilatations and inflations with neither benefit nor arrest of the progress of deafness.

On otoscopic examination, 13 showed definite thickening of the tympanic membrane, in one there was a chronic perforation with cholesteatoma, while in three the membrane was of normal thickness. Retraction, varying from moderate to marked, was present in 15 cases.

The light reflex was present in 15 cases, but normal in only six; in all others it was restricted; in only one was it absent.

Nose and throat examination was essentially negative except in those cases which had undergone nasal operations.

In only one instance was sinus disease demonstrated, although several patients gave a history of infection and treatment by irrigation.

Nasoscopic examination was entirely negative in all but two instances where congestion of the mucous membrane and slight impingement by adenoid tissue upon the Eustachian orifice could be demonstrated.

Bone conduction audiograms showed an equality of response to air conduction in nine cases, greater than air conduction in seven, and less than air conduction in one. This particular finding is based entirely upon bone conduction audiograms made with the Sonotone bone conduction receiver and a special Piezoelectric crystal instrument driven by a General Radio beat frequency oscillator. Appropriate masking was used in every instance. From the standpoint of bone conduction, no patient had any significant involvement of the neural mechanism.

A definite diagnosis of chronic catarrhal otitis media was made in 13 cases; in one there was a questionable diagnosis of otosclerosis, as against 11 such made previously. In three cases, diagnosis of chronic catarrhal deafness, of undetermined etiology, was made.

Factors remote from the ear and upper respiratory tract were found in three patients. In one a definite hypothyroidism; in the second a possible drug addiction, and in the third acquired syphilis. In this latter case there was no apparent connection between the hearing loss and the infection.

The extreme variations, mentioned below, appeared as follows: Minus 14.6 dcb. at 8,192 cycles in a case with definite chronic catarrhal otitis media, a diagnosis arrived at both from history and examination. The positive extreme, plus 22.8 dcb. at 512 cycles, in a patient with chronic catarrhal otitis media, plus definite hypothyroid symptoms. This particular patient has exhibited an annoying tinnitus during every audiometric examination.

Although irrelevant so far as the present discussion is concerned, attention must be called to the preliminary diagnosis of otosclerosis and the fact that every one of these patients had been treated by dilatation and inflation. In no instance was the tympanic membrane completely normal.

The hearing examinations were made in a soundproof room using two types of audiometers, the Western Electric 2A and the Sonotone. Tests on a given individual were made on one instrument so that, regardless of differences between instruments, variations between audiograms may be considered valid. Three separate operators were used, 80 per cent of all tests being made by one operator, with 95 per cent of the tests on any one patient made by a single operator. We feel that the disadvantage of differing techniques of two operators is sufficiently minimized. As a matter of fact, it is probable that the introduction of some new blood into the measurements prevents possible technical peculiarities of an individual operator from being too prevalent and thus influencing the spread of results to a marked degree.

The ages of the patients ranged from 16 to 47 years, with the average at 32 years; hearing loss at 1,024 cycles ranged

from 35 to 75 dcb., with average at 47. The audiograms were made over an average period of 13 months, the range being from two to 28 months. No fewer than 10 audiograms on one patient were used in the compilation.

Averages were calculated for each patient for frequencies from 128 cycles to 8,192 cycles and standard deviations of the individual measurements computed. The standard deviation is indicative of the error present in measuring hearing, based on the total number of tests of a single frequency and individual. The averages of the standard deviations which indi-

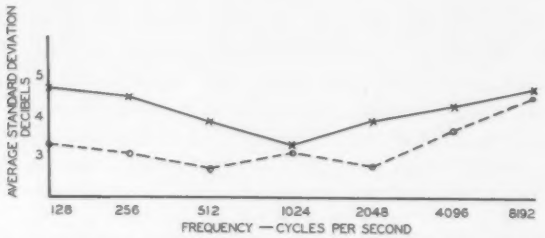

Fig. 1. Average standard deviation as a function of frequency.

TABLE I.

Average Standard Deviations and Probable Errors, in Decibels, of 297 Audiograms on 17 Ears.

Frequency	128	256	512	1,024	2,048	4,096	8,192
Standard deviation	4.64	4.45	3.88	3.28	3.91	4.23	4.67
Probable error	±.22	±.27	±.26	±.17	±.16	±.20	±.22

cate the error in the general run of audiograms are shown in Table I and in the solid curve of Fig. 1.

The error is a minimum at 1,024 cycles, climbing at both the higher and lower frequencies. The data show an error at 8,192 cycles only slightly greater than at 128 cycles; however, due to the fact that not all patients heard the highest frequency and some of the others showed no response part of the time, the results on this frequency are less definite than those on the lower frequencies. The comparison of hard-of-hearing with normal ears is demonstrated by a group of 126 control audiograms taken on seven normal ears. These data, which

appear in Table II and in the dashed curve of Fig. 1, do not show the smooth change with frequency exhibited by the data on the hard-of-hearing, but the deviations at all frequencies are appreciably smaller. The rise in the curve at 1,024 cycles is due to an inexplicably high error of one of the seven individuals.

TABLE II.

Average Standard Deviations and Probable Errors, in Decibels, of 126 Audiograms on Seven Normal Ears.

Frequency	128	256	512	1,024	2,048	4,096	8,192
Standard deviation	3.34	3.11	2.74	3.16	2.80	3.73	4.50
Probable error	±.29	±.22	±.23	±.26	±.23	±.43	±.44

It must be noted that this control group forms a less desirable comparison than might be wished for, since the subjects were accustomed to listening to threshold sounds and hence, in general, probably responded more accurately.

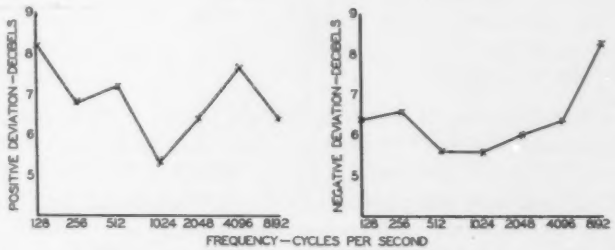

Fig. 2. Averages of maximum deviations plotted as a function of frequency.

An idea may be formed of the range of audiograms of the hard-of-hearing by inspecting the maximum deviations (in both positive and negative directions) of the hearing of each individual. These extreme deviations of each patient from the mean of all measurements on that patient have been averaged for the group of 17 patients and are shown in Table III and Fig. 2.

As might be expected, the minimum falls again at 1,024 cycles, but the trend on each side of the minimum is not well

TABLE III.

Averages of Maximum Deviations (in Decibels) in Positive and Negative Directions of Individual Audiograms from the Average for Each Patient.

Frequency	128	256	512	1,024	2,048	4,096	8,192
Positive deviation	8.2	6.8	7.2	5.3	6.4	7.7	6.4*
Negative deviation	6.4	6.6	5.6	5.6	6.0	6.4	8.3*

*Not a good average.

defined, as in the case of standard deviations. The extreme deviations for all patients at each frequency are shown in Table IV.

TABLE IV.

Extreme Maximum Deviations (in Decibels) in Both Directions from the Average.

Frequency	128	256	512	1,024	2,048	4,096	8,192
Positive deviation	19.7	14.2	22.8	15.0	12.5	12.7	14.3*
Negative deviation	13.2	14.0	11.1	10.5	10.3	11.1	14.6*

*Not indicative.

There is no trend here with respect to frequency. It is noteworthy that such large occasional deviations can occur in measurements, without increasing the average error to a more marked extent.

It is interesting to examine the data with a view toward determining the limit of accuracy to be expected from a single audiogram in comparison with multiple audiograms. The average standard deviations indicate that something less than plus or minus 5 dcb. and greater than plus or minus 3 dcb. is to be expected as error. The approach from another angle is shown in Table V.

TABLE V.

Comparison of First Audiogram and Average of All Audiograms.

Frequency	Accurate to One Step (±2.5 Dcb.)		Accurate to Two Steps (±5.0 Dcb.)	
	Number	Per Cent	Number	Per Cent
128	8	47.1	13	76.5
256	6	35.3	9	52.9
512	10	58.8	17	100.0
1,024	12	70.6	13	76.5
2,048	7	41.2	15	88.2
4,096	5	29.4	13	76.5
8,192	5	35.7	9	64.3
Total	53 out of 116 or 45.7 per cent		89 out of 116 or 76.7 per cent	

Here the first audiogram of every patient is compared with the average of all made on that patient (in no case fewer than 10), and the results calculated in terms of the percentage of instances in which the first audiogram agreed with the average to within plus or minus 2.5 dcb. (hereafter referred to as one step on the audiometer), and plus or minus 5 dcb. (hereafter referred to as two steps on the audiometer). The greatest precision occurs at 1,024 cycles, which is accurate to one step 70.6 per cent of the time. Taken as a whole, without attempting to give one frequency greater import than another, the audiograms are accurate to one step 45.7 per cent, or somewhat less than half of the time; 1,024 cycles is correct to two steps every time, and the frequencies as a whole are correct 76.7 per cent of the time. Carrying the examination one step further, the averages of the first two audiograms were compared with the average of all with the result that 58.6 per cent of the audiograms are accurate to within one step, and 87.1 per cent are accurate to within two steps (see Table VI).

TABLE VI.

Comparison of Average of First Two Audiograms and Average of All Audiograms.

Frequency	Accurate to One Step (±2.5 Dcb.)		Accurate to Two Steps (±5.0 Dcb.)	
	Number	Per Cent	Number	Per Cent
128	15	88.2	16	94.1
256	9	52.9	14	82.4
512	14	82.4	15	88.2
1,024	11	64.7	17	100.0
2,048	5	29.4	11	64.7
4,096	9	52.9	15	88.2
8,192	5	35.7	13	92.9
Total	68 out of 116 or 58.6 per cent		101 out of 116 or 87.1 per cent	

TABLE VII.

Comparison of Average of First Three Audiograms and Average of All Audiograms.

Frequency	Accurate to One Step (±2.5 Dcb.)		Accurate to Two Steps (±5.0 Dcb.)	
	Number	Per Cent	Number	Per Cent
128	10	58.8	17	100.0
256	11	64.7	17	100.0
512	16	94.1	17	100.0
1,024	14	82.4	17	100.0
2,048	6	35.3	14	82.4
4,096	9	52.9	15	88.2
8,192	6	42.9	11	78.6
Total	72 out of 116 or 62.1 per cent		108 out of 116 or 93.1 per cent	

Carrying this still further (see Table VII), the averages of the first three audiograms were compared with the average of all, resulting in increasing the over-all accuracy to 62.1 per cent to one step, and 93.1 per cent to two steps. The accuracy of the first four frequencies is 100 per cent to two steps on average of three audiograms. This same procedure was carried out on the controls for only the first audiograms (see Table VIII); the over-all accuracy is 55 per cent to one step as against 45.7 per cent for the hard-of-hearing, and 82 per cent to two steps as against 76.7 per cent for the hard-of-hearing. Thus, in the control group used, the normals show a greater accuracy.

TABLE VIII.

Controls — Comparison of First Audiogram and Average of All Audiograms.

Frequency	Accurate to One Step (±2.5 Dcb.)		Accurate to Two Steps (±5.0 Dcb.)	
	Number	Per Cent	Number	Per Cent
128	4	57.0	6	86.0
256	2	40.0	5	71.0
512	5	71.0	7	100.0
1,024	5	71.0	5	71.0
2,048	4	57.0	6	86.0
4.096	4	57.0	6	86.0
8,192	3	43.0	5	71.0
Total	27 out of 49 or 55 per cent		40 out of 49 or 82 per cent	

TABLE IX.

Comparison of Hearing Loss at 128 Cycles with Respect to 256 Cycles.

Hearing at 128 Cycles	Number of Audiograms	Per Cent of Total
15 dcb. better than 256	10	3.4
10 dcb. better than 256	79	26.7
5 dcb. better than 256	124	41.9
Equal to 256	69	23.3
5 dcb. poorer than 256	12	4.0
10 dcb. poorer than 256	2	0.7

Every otologist has noticed the rather striking manner in which the patients respond to the low frequencies even in audiograms of quite profound loss. Table IX shows a comparison between the hearing loss at 256 cycles and 128 cycles for the patients used in the results given above. It is remarkable that only 4.7 per cent of the audiograms show poorer hearing at 128 cycles than at 256 cycles. The correlation

coefficients for adjoining frequencies were calculated; the coefficient between 128 and 256 cycles is .915 ± .040; between 256 and 512 is .891 ± .050; between 512 and 1,024 is .728 ± .114. The significance of the correlation coefficient is in denoting the closeness to which one frequency follows changes in the other, a high coefficient indicating good conformity; the maximum coefficient, unity, indicating exact conformity. The inference drawn from the coefficients is that there is a remarkably close relationship between 128 and 256; a less striking relationship for the higher frequencies. From the relationships in these data, formulae were derived to predict the values of the lower frequency in each of the three pairs. These formulae are as follows:

Hearing loss at 128 cycles equals .916 times hearing loss at 256 cycles minus 2.0.

Hearing loss at 256 cycles equals .960 times hearing loss at 512 cycles minus 3.9.

Hearing loss at 512 cycles equals .932 times hearing loss at 1,024 cycles minus .8.

One hundred audiograms were chosen at random from the files and these formulae applied to determine how well the hearing loss at the lower frequency could be calculated from the upper frequency of the pair. Audiograms of patients included in the data from which the formulae were derived were not used in this survey. It was found that 34 per cent of the calculated values agreed to within one step of the audiometer, and 66 per cent agreed to within two steps of the audiometer with the observed values at 128 cycles. These values are to be compared with 47.1 per cent accuracy to one step, and 76.5 per cent accuracy to two steps of the audiograms at 128 cycles. At 256 cycles the accuracy is 20 per cent and 39 per cent for comparison of observed and calculated results. The accuracies of the audiograms were 35.3 per cent and 52.9 per cent. At 512 cycles the accuracy is 25 per cent and 38 per cent, as against 58.8 per cent and 88.2 per cent for the audiograms. It may be seen that at 128 cycles the agreement is quite reasonable, so that it may well be possible to calculate losses at 128 cycles if this lowest frequency has not been measured. Without attempting to account for the apparent tenacity of these low frequencies, the

question may be raised concerning the necessity of measuring at 128 cycles, since it is so closely related to 256 cycles; apparently the audiogram would be as effective.

The audiograms were also examined to determine the relationship between the average of all audiograms, and the first and last audiograms. Table X, which shows the number of hearing measurements better than, equal to and poorer than average for both the first and last audiograms, indicates that there is some evidence of the audiogram improving with repetition. This is purely a statistical effect and is not large enough to be clearly significant within the error of the audiograms as evidenced by the present study.

TABLE X.

Comparison of First and Last Audiograms with Average of All Audiograms.

Frequency	128	256	512	1,024	2,048	4,096	8,192
First better than average	6	6	8	6	6	9	6
First equal to average	0	0	2	2	0	0	1
First poorer than average	11	11	7	9	11	8	8
Last better than average	10	10	7	10	7	7	8
Last equal to average	0	0	2	3	0	0	1
Last poorer than average	7	7	8	4	10	10	6

SUMMARY AND CONCLUSIONS.

1. The audiograms of the hard-of-hearing individuals used in the present investigation exhibit an inherent error of slightly less than 5 dcb., the error being a function of frequency with 1,024 cycles showing the smallest error. If this minimum error at 1,024 cycles may be considered indicative of maximum ease of listening, the procedure of using this frequency as the starting point in an audiogram may be considered justified. Regardless of the reason for this accuracy, it seems reasonable to begin measurement at the most accurate frequency. The audiograms made on normal ears are slightly more accurate.

2. Large occasional deviations from the average are experienced and remain unexplained. Evidently these large deviations are to be expected in hard-of-hearing patients, but large deviations occurring too frequently should not remain unexplained.

3. Three audiograms when averaged show an error which is so much smaller than a single audiogram that the procedure seems recommended whenever accuracy is desirable.

4. The lowest frequency used, 128 cycles, shows such a remarkable correlation to 256 cycles that there appears to be ample justification for terminating the audiogram with 256 cycles, especially in the case of certain patients where the audiogram is difficult to obtain.

5. There is a slight rise in the apparent acuity of hearing as registered by audiograms from the first of a series of audiograms to the last, even when time intervals of over two years elapse from first to last.

6. Variations greater than those obtained in this study are assumed to arise from some contributing factor of deafness; for example, tinnitus, therapy and infection.

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CALCULI IN THE SUBMAXILLARY GLAND AND WHARTON'S DUCT.*

DR. GOODLATTE B. GILMORE, New York.

Contrasted with the frequent occurrence of stones in the gall bladder and kidneys, calculi in the salivary glands are relatively rare. Reported cases in the literature are not frequent, and modern textbooks give the matter limited space. This is a subject of interest to the dentist, surgeon and otolaryngologist alike. The dentist often is the first to whom the patient turns for advice, since the symptoms are confused with those of dental origin.

Of the three salivary glands, the submaxillary or its duct is affected in 60 per cent of cases, the parotid and sublingual each contributing 20 per cent.[1] The disease is generally unilateral, the right submaxillary gland being involved more than the left.[2] Single stones are in the majority, multiple calculi being rare. It is a disease of middle life, from which males suffer more than females.

Chemically, salivary calculi consist of the carbonate and phosphate of calcium and are, therefore, opaque to the Roentgen ray. They may be large or small, smooth or irregular. A central prolongation into the lumen of the duct is commonly observed (see Fig. 1B). The formative process is a slow one. A stone was removed by Pilcher,[3] whose nucleus was a piece of grass which had penetrated the mucosa of the mouth 12 years before.

Theories have been advanced explaining the etiology of calculi in the submaxillary gland. Previous infection increases the tendency to their formation, calcium salts being deposited upon a bacterial centre. Stones whose nuclei consist of inflammatory epithelial debris and ray fungi are reported. The portal of entry for organisms is Wharton's duct. Barnhill[4] believes the thicker saliva of the submaxillary gland and the resultant slow upward movement through the duct account for the frequency of calculi in this location.

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Foreign bodies as a foundation upon which calcium salts are thrown down are exceedingly rare. In addition to Pilcher's[3] case, Barnhill[4] mentions a fragment of toothpick in the middle of a stone.

If infection is the sole causative factor, Ziegelman[5] thinks more calculi than can be demonstrated should be found. He advances the theory that there exists some dysfunction of the parathyroids and calcium metabolism. It would, therefore, seem logical to conclude that past infection in the submaxillary gland of a person whose calcium metabolism is faulty would explain the etiology. Research with this in view would be interesting.

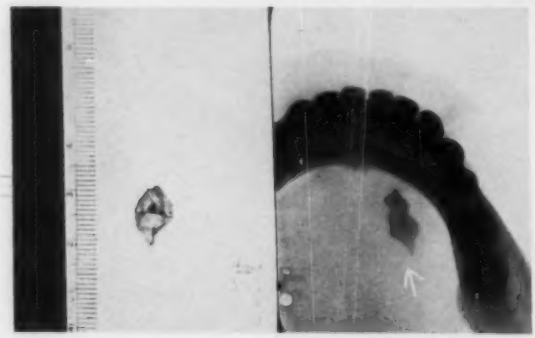

Fig. 1A. Fig. 1B.

Case 1.

Small calculi in the submaxillary gland or Wharton's duct are symptomless. As they increase to obstructive size, a local painful disturbance is complained of after eating, and swelling is noted along the course of the duct or in the submaxillary triangle. Saliva mixed with pus may be expressed from the duct's inflamed stoma; this phenomenon at irregular intervals the patient may have observed. This outflowing of secretion is accompanied by a temporary relief of symptoms.

An acute exacerbation of the ever-present chronic infection causes fever and leukocytosis, with increased pain and swelling. The liability to phlegmon of the gland or floor of the mouth must not be forgotten. A case to illustrate this is

reported by Childrey.[2] Between the acute obstructive inflammatory attacks, chronic thickening of the gland and duct is present. The stone may or may not be palpable.

The diagnosis is not hard. An X-ray will distinguish between a calculus and dental pathology. Malignancy of the gland and floor of the mouth should likewise be ruled out. The intermittent character of the pain and swelling, the discharge of saliva and pus from the duct, and the findings from

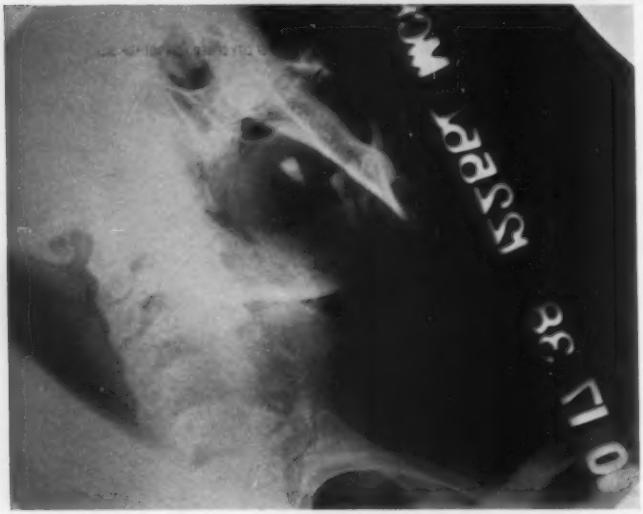

Fig. 2. Shadow of calculus in submaxillary gland. Case 2.

palpation in the floor of the mouth or submaxillary triangle should lead one to suspect the presence of a calculus. The X-ray clinches the diagnosis.

There is always a tendency to spontaneous expulsion of the smaller concretions, and they have been picked from the mouth of Wharton's duct where their progress has been arrested. Probing or dilating the duct to facilitate expulsion is condemned on the grounds of possible injury and resultant infection.

When a case is seen with acute inflammation of a mild nature, a conservative, waiting attitude should be assumed.

Warm saline irrigations and externally hot applications are employed. If a true phlegmon exists, incision and drainage are indicated, as in Ludwig's angina from any other source. Surgical removal of the stone should not be attempted in the presence of acute infection. The treatment of a large stone which obviously would not pass spontaneously depends upon its location.

When the calculus is in the duct, a longitudinal incision is made through the mucosa in the mouth over the stone's exact location. This should be generous in length and the duct freely

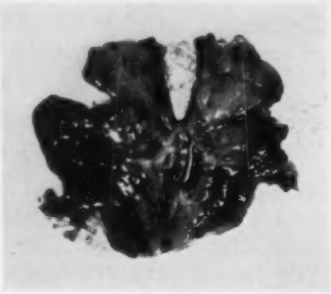

Fig. 3. Submaxillary gland sectioned to show calculus. Case 2.

opened. It then becomes a simple matter to lift the calculus from its bed with a dull curette. Suturing the wound is not necessary.

A calculus in the pulp of the submaxillary gland or immediately adjacent thereto demands surgical extirpation of the gland. An accurate knowledge of the anatomical relations should be required before this is attempted. Ziegelman's[5] article contains excellent drawings of these relations.

The incision extends below and parallel to the inferior border of the mandible, from the angle, anteriorly to a point near the symphysis menti. This is carried through the skin and overlying layers to the superficial layer of the deep fascia, thereby exposing the surgical capsule of the gland. This is incised over its entire length. Severing the cervical branch of the facial nerve which supplies the platysma myoides has no noticeable effect. The flaps are retracted and the gland is

dissected free in all directions with dull or sharp instruments, as becomes necessary. Chronic inflammatory thickening makes for easier identification of the gland borders but adhesions formed as a part of this process add to the difficulty of separation. The facial vein passing over the centre of the gland and the external maxillary artery at its posterior border are ligated. The lingual nerve internal to the gland is identified and avoided. The hypoglossal nerve is safely below the operative field.

When the dissection has completely encircled the gland, there remains only the ligation and cutting of Wharton's duct close to its point of emergence. The gland can now be removed. A small drain is inserted at the middle of the wound and the skin edges accurately approximated with silk or horsehair sutures.

The operative results are gratifying and a barely noticeable scar remains. Dryness of the mouth does not occur.[4]

Photographs of salivary calculi removed in two cases are presented. In Case 1 (see Fig. 1A), the stone was located in Wharton's duct anteriorly. In Case 2 (see Figs. 2 and 3), the stone was within the substance of the submaxillary gland. In Case 1, the stone was delivered through an incision in the floor of the mouth; in Case 2, the gland was removed (see Fig. 3). Both patients made a satisfactory recovery.

I am grateful to Dr. Clarence H. Smith for reading and correcting this paper.

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2940 Grand Concourse.

MINNESOTA ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY.

SECTION ON OTOLARYNGOLOGY.

Meeting of May 31, 1939.

Audiometers and Hearing Aids in Otologic Practice. Dr. Horace Newhart and Henry E. Hartig, Ph.D. (by invitation).

DR. NEWHART: Mr. President, members of the Academy and guests: We greatly appreciate being with you as your guests of honor this evening. I am especially fortunate in sharing this honor with Dr. Hartig, who is a recognized authority on electroacoustics as related to otology. To him belongs the credit for valuable research on audiometers and hearing aids. He has done the real work, while I have been instrumental only in instigating it through suggestions based on some of the clinical aspects of the subject.

Our purpose has been to stimulate interest in raising the standards of manufacture, performance and distribution of audiometers and electrical hearing aids. This work was made possible by grants from the Graduate Research Committee of the Medical School of the University of Minnesota.

In line with our efforts, the Council on Physical Therapy of the American Medical Association in 1936 organized its Committee of Consultants on Audiometers and Hearing Aids, in whose deliberations we have both participated. The Council has generously undertaken to set up minimum specifications for the construction, performance and ethical distribution of audiometers and electrical hearing aids to protect the medical profession and the public from being sold inferior products. The Committee, after making careful investigation of the advertised claims of the manufacturers, impartial laboratory tests of the instruments and the methods employed in their distribution, recommends for "acceptance" only such products as meet certain minimum standards.

Of the audiometers which have been submitted for "acceptance," only one to date has met the requirements. Others have very nearly fulfilled the requirements and they may soon be so improved that they will become "acceptable" as instruments suitable for clinical use.

Various audiometers of different makers have different features of merit, such as a continuous frequency sweep range, or only selective sweep at octave or half octave intervals; bone conduction receivers as well as air conduction receivers; special masking devices for both air and bone conduction, and built-in microphones for testing with speech and for ease in conversing with severely hard-of-hearing persons.

At the present time the prospective purchaser of an audiometer must decide which features he most requires in his work and should secure from the maker a written guarantee that within a reasonable time he will remodel or replace at cost the instrument with one which will meet all the requirements of the Council.

Two services in the field of audiometry which the Committee should undertake are:

1. The adoption of a standardized chart and uniform symbols for recording the findings so that one observer can readily read and interpret an audiogram made by any other observer. Work on this problem is already well under way.

2. The investigation and standardization of the performance and methods of applying audiometers especially designed for screening purposes to detect

hearing deficiencies in large groups of school children and industrial workers. Already such instruments are available and their use is rapidly increasing. Since legislation has been passed in several States making mandatory the testing of all school children by the audiometer, it is very desirable that they be so standardized at an early date that they will yield comparable results.

Dr. Hartig at this point discussed and demonstrated some of the principles involved in the construction and application of audiometers and hearing aids.

(To be continued in a succeeding issue.)

BOOK REVIEW.

Standards on Electroacoustics 1938, published by the Institute of Radio Engineers, Inc., 330 West 42 Street, New York City, 1938, 37 pages, paper covers, price 50 cents.

During the past two decades, the science of acoustics has developed out of all recognition of its former self. During this rapid evolutionary process, a number of new terms have been formulated. This booklet fills a definite need in that it makes available in a handy form the tentative standards and accepted terminology in the field of electroacoustics. Although published by the Institute of Radio Engineers, the definitions contained are the tentative standards and concepts of the Acoustical Society of America. The use of this booklet by those actively engaged in acoustics will go far to clear up certain hazy conceptions of its terminology and a more thorough understanding of standard reference levels.

C. E. H.